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The Mining Magazine

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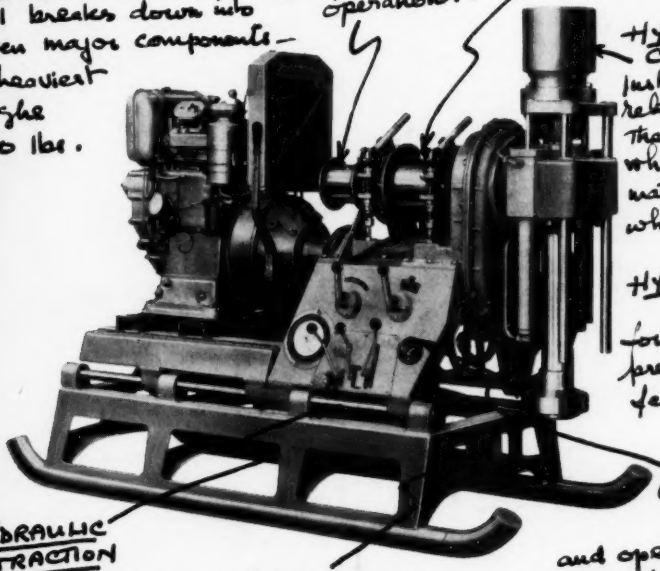

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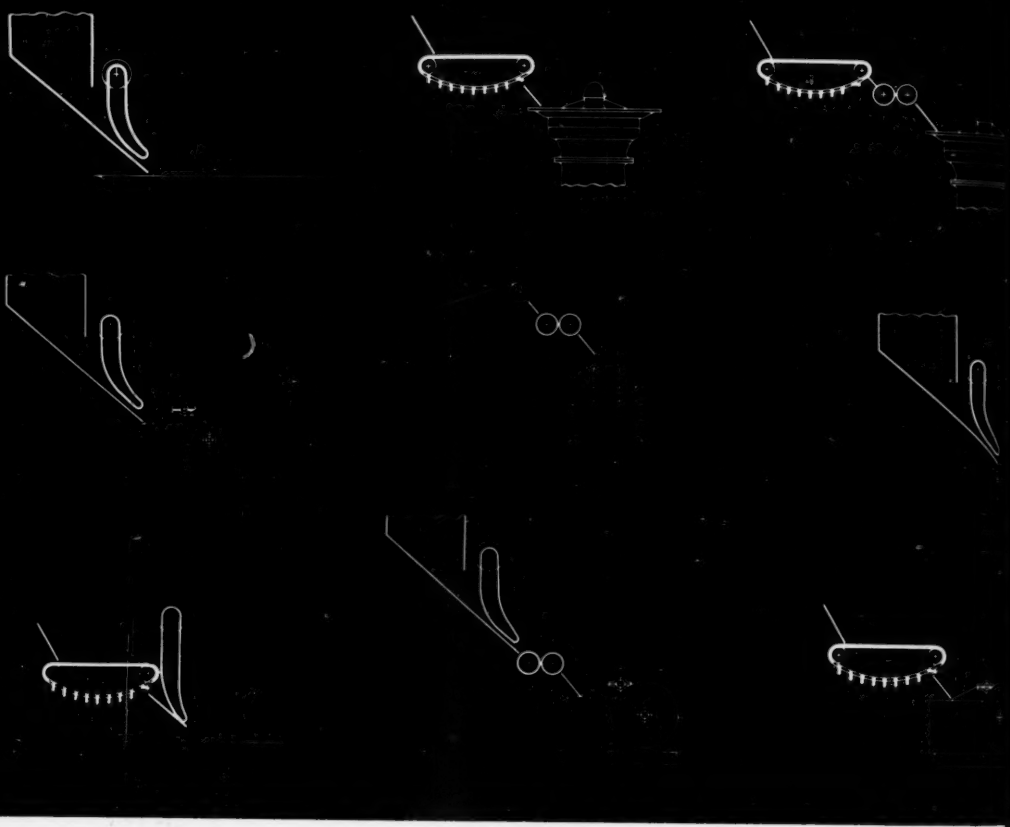

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EDITORIAL

THE next president of the Institution of Mining Engineers is to be Mr. Robert A. Moore, who will succeed Mr. R. G. Baker at the 67th annual general meeting to be held in London on January 26, 1961. Mr. Moore was educated at Kelvinside Academy and Glasgow University and after wide practical experience in coal mines in England, Scotland, and Wales he obtained his First Class Colliery Manager's Certificate in 1932. In the same year he joined the firm of A. G. Moore and Co., Ltd., becoming general manager of the company in 1936 and chairman of directors in 1938. In 1943 he succeeded Sir Charles Reid as Regional Production Director, Scottish Region, Ministry of Fuel and Power. On the nationalization of the coal-mining industry in 1947 Mr. Moore was appointed Deputy Production Director and in 1956 Production Director of the Scottish Division, National Coal Board, and in 1958 he became Reconstruction Director for the same Division. Mr. Moore joined the Institution in 1933 and has been a Member of Council since 1941. He was President of the Mining Institute of Scotland in 1955 and 1956 and was awarded the O.B.E. in 1946.

UNDER a new development scheme to cost a total of £32,500,000 the Appleby-Frodingham Steel Co., Ltd., plans to increase its productive capacity for iron and steel and to install a new rod-bar mill. At the same time Samuel Fox and Co., Ltd., is to add 100,000 tons per annum to its steel-making capacity. Both works are branches of the United Steel Companies, Ltd. At present Appleby-Frodingham has a planned annual productive capacity of slightly exceeding 1,000,000 tons of plates and sections, but by the end of 1964 this figure will approach 1,400,000 tons of finished products per annum. To meet the demand United Steel's ore mining branch plans to increase the level of its ironstone campaign from 6,190,000 tons per annum to 7,700,000 tons, all of which will be extracted from the company's orefields in North and South Lincolnshire and Rutland. It will also be necessary to produce additional metallurgical coke for the Scunthorpe blast-furnaces and the United Coke and Chemicals Co., Ltd., is to provide an additional 323,000 tons per annum by doubling the size of its Brookhouse coke-oven plant and by adding 50% to the capacity of its Orgreave plant.

MINERAL exports from Tanganyika Territory in the first quarter of the current year are 136% higher than in the corresponding period of 1959, the value being £1,911,652, against £809,634. This is largely due to increased exports of diamonds, mica, tin, and lead concentrates. In the period diamonds of an estimated value of £1,312,803 were exported, while gold bullion exported amounted to an estimated value of £205,787. Exports of lead concentrates rose from an estimated value of £134,659 for 1959 to £337,500 for the first three months of this year and tin concentrates from £7,966 to £16,658. Mica exports also rose from £8,633-worth last year to an estimated £13,309. Last month the Minister for Mines and Commerce, Mr. D. N. M. Bryceson, opened a course of instruction in prospecting for minerals at the Land Planning Training Centre in Morogoro. Attended by 30 Africans the course was conducted by the Department of Mines and intended to last for three weeks, during which time the students were instructed in the simpler aspects of prospecting, mining, and preparation for the marketing of mica and its associates—the principal mineral likely to be found and profitably exploited by small-workers in the Tanga and Eastern Provinces.

IN its report for 1959 [1] the International Tin Research Council discusses several new lines of investigation which are being followed in metallurgy and in organotin chemistry. In the metallurgical field systematic investigations are continuing into the alloys of tin with the newer metals titanium, zirconium, and niobium, while the effects of tin in cast iron and in steels are being further studied. Practical trials are now being made with cast irons containing prescribed additions of tin. In the electrodeposition field it has been found that bright deposits of tin can be made, using wood tar additions in the plating vat. The Institute is trying to discover which constituents of the tars are effective so that the process can be simplified. At the same time several new studies of the properties of tinplate are mentioned and a new method of assessing porosity of tin coatings by measurement of flow of current is described. In the chemical

[1] International Tin Research Council Annual Report, 1959. Greenford, Middx.: Tin Research Institute.

field organotin researches, it is stated, are pointing the way to new types of compounds of greater complexity which are likely to have industrial uses.

The report gives a long account of the activities of the Institute and its branches in other countries. Over 2,000 requests for technical help were received during the year, while the Institute continued to organize lectures, conferences, and exhibitions and distributed its publications and quarterly journal *Tin and its Uses* to all countries.

Uranium in Canada

"A Survey of the Uranium Industry in Canada," by Mr. J. W. Griffith, of the Mineral Resources Division of the Department of Mines and Technical Surveys in Ottawa, has recently become available.[1] In 1958 the Canadian uranium ore production reached a total of 12,481,500 tons in 25 operating mines and the total mill capacity reached 43,000 tons of ore a day in 19 treatment plants, the principal producing areas being the Elliot Lake or Blind River district in Ontario which produced 68% of the total concentrates; the Beaverlodge area in northern Saskatchewan which produced 22% of the total; the Bancroft area of Ontario (7%), and the Northwest Territories (3%). The author gives the total reserves of uranium ore in Canada at the end of 1958 as at approximately 328,000,000 tons averaging 0·12% U_3O_8, these being the largest known reserves in the world in terms of uranium oxide. Reserves in the Elliot Lake district constitute about 94% of the total.

The net result of the phenomenal growth in the industry, the author points out, is that it is generally realized throughout the western world that there is now an oversupply of the metal, the demand for uranium being not expected to reach the supply until about 1968. In recent years large deposits have been discovered in the United States and it soon became apparent that the United States Atomic Energy Commission might reduce its purchases of Canadian uranium. On November 6, 1959, the U.S.A.E.C. actually announced that it would not exercise any portion of the options to purchase Canadian uranium in the post-1962 period. As a result of this decision the Canadian Minister of Trade and Commerce announced a change in policy with respect to the supply of uranium under the existing contracts. Arrangements were made by Eldorado with the U.S.A.E.C. and the United Kingdom Atomic Energy Authority, which also holds contracts for the purchase of Canadian uranium, to allow a "stretch-out" of deliveries of uranium to December 31, 1966. To implement the stretch-out of Canadian production transfers of uranium sales contracts between the Canadian companies in production is now to be permitted. The report under review suggests that although the effect of developments on the structure of the industry and on its rate of growth during the next decade cannot be appraised at this time considerable reorientation and adjustment is likely to take place prior to expiry of existing contracts in 1962 and 1963.

[1] Mineral Information Bulletin MR 34.

The Institution of Mining and Metallurgy

This year the annual dinner of the Institution of Mining and Metallurgy was held on May 5 in Goldsmiths' Hall, London, with Dr. J. H. Watson, the retiring president, in the chair. Some 160 members and their guests were present for the occasion, which was graced by the presence of the Earl of Perth, Minister of State for Colonial Affairs, and Dr. A. J. Clasen, the Luxembourg Ambassador. Proposing the toast of the Institution Lord Perth spoke appreciatively of the service that exploration for minerals had rendered to opening up backward territories in so many parts of the world. In the development of the old Colonies and overseas areas mineral development had provided the basis for economic advancement, advancement which was now becoming evident as new dominions were being brought into the Commonwealth. In reply the president spoke, he said, particularly for those members whose work was overseas, work which, he agreed, was a benefit to the areas in which they operated. Their experience, however, was at the Institution's disposal and such experience abroad was proving of immense help when the future of mining education was being considered. This was a subject near to the heart of the Council and Dr. Watson thought that considerable progress had been made. After a brief reference to the Mineral Processing Congress just concluded he reminded members of the Commonwealth Congress to be held in South Africa next year and hoped that they would help to make it a success. The toast of "Our Guests" was proposed by the president-elect, Professor David Williams, and felicitously answered by the Luxembourg Ambassador.

At the annual general meeting of the Institution to be held on May 19 the new president will be inducted into the Chair and then deliver his address on "Progress in Mining Geology: Training, Research, and Development." At this meeting also there will be the usual presentation of awards, those for 1959 having just been announced. This year Gold Medals go to Mr. E. D. McDermott, "in recognition of his distinguished services to the mining industry and profession and of his services to the Institution as its representative on the Governing Body of the Imperial College of Science and Technology for 15 years," and to Mr. Julius Kruttschnitt, "in recognition of his distinguished services to the mining industry in Australia." Honorary Membership of the Institution has been conferred on the Rt. Hon. Lord Robins "in recognition of his services to the mineral industry, particularly in Southern Africa," on Sir Reginald Patrick Linstead "in recognition of his services to the profession of mining and metallurgical engineering in the field of education," and on Mr. G. A. Whitworth "in recognition of his services to the mining industry and profession on the occasion of his retirement from the Principalship of the Camborne School of Metalliferous Mining." "The Consolidated Gold Fields of South Africa Limited" Gold Medal for the session 1958–59 has been awarded to Mr. S. C. Newman for his paper entitled "Sinking No. 2 shaft, Harmony Gold Mining Co., Ltd., O.F.S." and the same company's Premium to Mr. Felix Mendelsohn for his paper on the "Structure of the Roan Antelope deposit." Finally, the "Arthur Claudet" Student's Prize has been awarded to Dr. H. N. Rhoden for his paper entitled "Structure and Economic Mineralization of the Silvermines District, County Tipperary, Eire."

Coal in Northern Rhodesia

A report on the Karroo System in the Zambesi Valley now available from Northern Rhodesia [1] follows the completion of geological mapping in the area. It is particularly noteworthy for a complete and exhaustive account of the Kandabwe coalfield, preliminary information regarding which was made available some years ago. Six of the seven deposits in the area are dismissed as of no economic importance, but the seventh, the Kandabwe seam, discovered in 1952 when local Africans drew attention to a thick bed of coal exposed on the banks of the Kandabwe River, is described by the author as "a national asset which could prove of value in the future . . . although it is unlikely to be of immediate economic importance."

Following the discovery of the seam development work by shaft sinking along the strike began in the middle of 1953, drilling operations proving that the length of the main seam was about 4 miles, the variation in thickness being between 22 ft. and 7 ft. The total proved and possible reserves of the deposit now amount to about 17,000,000 long tons, it is thought, after making a 20% allowance for irrecoverable coal. The report states that the quality of the coal in the seam might fairly be described as low-grade, analyses of more than 300 samples showing that the average ash content is of the order of 24% and that the calorific value was 10,200 B.Th.U./lb. Rather better values were produced by analyses of the lowest 6 ft. of coal in the area of proved reserves. Owing to the high angle of dip in the seam and the nature of the overburden open-cast mining is not considered practicable, while the steepness of dip would probably make mining methods more expensive than at the Wankie field in Southern Rhodesia, with which, geologically, the Kandabwe deposit has an overall similarity. In the words of the author: "It appears that the immediate prospects for development of the Kandabwe area are not good, though much would depend upon the price at which the coal could be marketed and the demand that could be created for it in the face of competition from Wankie and the coalfields of the Union of South Africa. Nevertheless, the existence of a small potential coalfield has been proved where none was suspected and there could be no doubt that in more favourable circumstances the coal would certainly be worked."

The author concludes: "The whole of the Karroo rocks and the Gwembe District have now been investigated with special regard to their coal resources. . . . It seems likely that enough is now known regarding the cause and effect of coal formation in the Gwembe District to state that, under the prevailing conditions, the formation of thick seams of coal must have been a rarity and the combination of circumstances which led to the deposition of the Wankie coal is unlikely to have been repeated elsewhere in the region."

[1] TAVENER-SMITH, R. "The Karroo System and Coal Resources of the Gwembe District, South-West Section." *North. Rhod. Geol. Surv. Bull.* No. 4. Price 30s. Lusaka: Ministry of Labour and Mines.

MONTHLY REVIEW

Introduction.—Uncertainties developing as the time approaches for the "Summit" talks, together with uneasiness aroused by affairs in Southern Africa tend to undermine business confidence. At the same time industrial activity is sustained at a high level and commodity prices, generally speaking, remain firm.

Transvaal.—The Chamber of Mines returns for March show a gold output of 1,664,514 oz., making with 38,744 oz. from outside mines a total of 1,703,258 oz. for the month. The April figures create a new record, showing a total output of 1,771,030 oz., made up of 1,734,310 oz. and 36,720 oz. from outside. At the end of April there were 385,841 natives at work on the gold mines, as compared with 388,860 at the end of March.

In his statement on the report and accounts for 1959 the chairman of ROSE DEEP says that mining operations were continued on a marginal basis during the year and it was found impracticable to maintain a milling rate at the previous year's level. There was accordingly an overall drop of 181,000 tons in the total ore milled. It was necessary to withdraw further from the lower levels of the mine, but the programme of withdrawal was so regulated to ensure that all usable material was reclaimed and brought to surface. The policy of withdrawing to the 18th level is, he said, proceeding satisfactorily.

With the recent dividend notice shareholders of WITWATERSRAND GOLD MINING were informed that the company has now returned the whole of its issued capital, with the exception of a nominal amount, thus reducing the par value of the shares from the original 20s. to the present figure of 3d. per share. The company has now decided to revert at this stage to the payment of dividends.

In the three months to March 31 last DOMINION REEFS (KLERKSDORP) treated 123,960 tons of ore and recovered 131,912 lb. of uranium oxide. Operations resulted in a working profit of £245,153.

At the first annual meeting of WESTERN AREAS GOLD MINING held in Johannesburg earlier this month shareholders were informed that good progress had been made with the erection and equipment of surface installations and in shaft sinking. Sinking commenced at the ventilation shaft on January 20 and at the main shaft on March 13. By May 5 the main shaft had reached a depth of 974 ft. and the ventilation shaft a depth of 2,178 ft., being an advance in the five weeks since April 1 of 618 ft. and 581 ft., respectively.

The report of WESTERN DEEP LEVELS for 1959 states that by the end of the year both shafts of the No. 3 Vertical Shaft system and the main shaft of the No. 2 Vertical Shaft system had passed out of the dolomites and through the Black Reef into the lavas. By the end of February, 1960, the No. 3 system had been sunk to its final designed depth of 6,354 ft. and the main shaft of the No. 2 system had reached a depth of 5,508 ft. and the ventilation shaft had entered the lavas and was at 5,226 ft. The main shaft of the No. 3 system is in the course of being stripped of sinking equipment preparatory to its being re-equipped for hoisting. In the meanwhile development has been started from the bottom of the ventilation shaft and as soon as the necessary pump chambers, waste passes, and other essential facilities have been provided it is planned to cross-cut on three levels to the Ventersdorp Contact Reef.

The operations of WESTERN REEF EXPLORATION AND DEVELOPMENT in 1959 resulted in a profit of £3,175,715, the accounts showing £3,659,133 available, of which dividends totalling 2s. 6d. a share require £875,000. In the year 1,582,000 tons of ore was milled and 418,098 oz. of gold and 708,954 lb. of uranium oxide recovered.

VAAL REEF EXPLORATION AND MINING reports a profit of £4,294,354 for 1959, dividends equal to 3s. 6d. a share requiring £1,837,500 of the £4,305,819 available. The company milled 1,088,000 tons of ore in the year, the gold recovery being 490,939 oz. and the uranium oxide output 608,000 lb.

The accounts of CROWN MINES for 1959 show a profit of £290,982 and £1,510,734 available for appropriation. Dividends totalling 3s. 9d. a share required £353,648 of this amount. In the year 419,708 oz. of gold was recovered from 2,626,000 tons of ore treated.

The report of EAST RAND PROPRIETARY MINES for 1959 shows a profit of £1,463,682 and an available total of £2,405,959, of which dividends totalling 3s. 6d. a share require £693,000. The mill crushed 2,625,000 tons of ore in the year and recovered 684,712 oz. of gold.

CITY DEEP reports a profit of £174,459 for 1959, the accounts showing £1,013,589 for appropriation, of which dividends equal to 1s. 3d. a share took £126,677. In the year 1,353,000 tons of ore sent to the mill yielded 282,108 oz. of gold.

Last month STILFONTEIN GOLD MINING announced that the Vaal Reef was intersected in the Toni shaft at a depth of 3,366 ft. The average of ten sections sampled over a channel width of 8·0 in. was 89·1 dwt. per ton for gold and 3·62 lb. per ton uranium, equivalent to 713 in.-dwt. and 28·96 in.-lb., respectively.

The operations of EAST DAGGAFONTEIN MINES in 1959 resulted in a profit of £423,370, the accounts showing £626,536 available, of which dividends totalling 1s. 3d. a share require £233,125. The company milled 1,208,500 tons of ore in the year and recovered 202,686 oz. of gold.

The report of DAGGAFONTEIN MINES for 1959 shows a profit of £4,525,528 and an available amount of £5,025,558, of which £1,575,000 is required for dividends equal to 4s. 6d. a share. In the year 573,962 oz. of gold and 610,540 lb. of uranium oxide were recovered from the 2,850,000 tons of ore treated.

The accounts of VOGELSTRUISBULT GOLD MINING AREAS for 1959 show a profit of £1,008,513 and a total of £1,159,998 available. Repayments of capital in the year absorbed £440,000. The mill crushed 1,091,000 tons of ore and recovered 242,679 oz. of gold, while the uranium plant recovered 210,758 lb. of uranium oxide.

ROBINSON DEEP suffered a loss of £72,469 in 1959, the accounts showing a credit of £11,272 carried forward. In the mill the 685,500 tons of ore crushed yielded 140,812 oz. of gold.

The operations of GEDULD PROPRIETARY MINES in 1959 resulted in a profit of £915,389, the accounts showing £1,270,825 available, of which £712,168 is required for dividends equal to 9s. 9d. a share. The mill treated 909,800 tons of ore, which yielded 165,739 oz. of gold.

EAST GEDULD MINES reports a profit of £1,683,150 from operations in 1959, the accounts showing that dividends equal to 3s. 8d. a share required £1,650,000 of the £2,237,234 available. In the mill 1,653,000 tons of ore was treated and 493,952 oz. of gold were recovered.

The accounts of WINKELHAAK MINES for 1959 show a profit of £503,651 and an unappropriated balance of £208,553 carried forward. The mill treated 908,000 tons of ore in the year and recovered 235,111 oz. of gold.

The AFRICAN METALS CORPORATION, which recently acquired the ferro-alloy works of another company as an extension of its own similar interests, is now proposing an increase of capital through a share issue to finance further extensions to its ferroalloy plant and the establishment of a factory to produce graphite electrodes at its Kookfontein sites, near Vereeniging. The factory will be operated in association with the Siemans-Plania group, will use such domestic raw materials as coal and tarpitch, and will have an output of about 3,000 tons a year of electrodes. In addition to the proposed share issue mentioned the African Metals Corporation proposes a capitalization of a portion of the reserves already used to finance its activities through a bonus share issue, in the ratio of one bonus share for four held.

In the three months to March 31 last the ROOIBERG MINERALS DEVELOPMENT COMPANY produced 276 long tons of tin concentrates, the estimated working profit for the period being £17,235.

The accounts of RAND MINES, LTD., for 1959 show a profit of £1,500,597 and £1,912,624 available. Dividends totalling 6s. per share require £855,298 after placing £625,000 to reserve; there was a balance of £432,326 to be carried forward.

Orange Free State.—The report of ST. HELENA GOLD MINES for 1959 shows a profit of £3,089,625 and a total of £3,920,847 available, of which dividends equal to 3s. a share require £1,443,750. In the year 558,433 oz. of gold were recovered from 1,810,000 tons of ore milled. No. 7 Shaft, which is being sunk to provide better ventilation, reached a depth of 3,247 ft. at the end of the year. No. 18 Level cross-cut, which is being developed towards the President Brand boundary, reached the shaft site earlier in the year at a depth of 4,013 ft. It is intended to sink the shaft past this point to an approximate depth of 5,500 ft. where it will connect with 23 or 24 Level.

Southern Rhodesia.—The BRITISH SOUTH AFRICA COMPANY has announced that its estimated gross revenue for the quarter ended March 31, after providing for the payment to the Northern Rhodesia Government of 20% of the net revenue derived from the exercise of its Mineral Rights in Northern Rhodesia, amounted to £3,076,000.

Northern Rhodesia.—RHODESIA BROKEN

HILL DEVELOPMENT should derive substantial benefits from the installation of the Imperial Smelting furnace now being effected and expected to be commissioned early in 1962. Lead and zinc extraction will be raised from about 60% to over 85% from current ore, while about 200,000 long tons of the two metals will be recovered from high-grade oxidized accumulations. At capacity operation output of lead and zinc will be increased respectively to 28,000 and 55,000 long tons from about 14,400 and 30,000 long tons per year. Including ancillary installations the total cost will be £4,350,000. Of the £3,550,000 to be provided £3,000,000 will be raised by two convertible note issues, this year and in 1962, and the balance appropriated from profits. Under existing metal prices and barring the unexpected dividends should be maintained. With the new smelting furnace commissioned alongside existing plant the feed, as now planned, will consist of 200,000 tons of mined ore a year and 30,000 tons to 40,000 tons of accumulated dumped material, against a total treated of 264,628 tons and 217,200 tons in 1959 and 1958. Over 1959 the total ore reserves were increased by 725,000 short tons to 5,870,000 short tons, which, apart from extended development, gives the mine an effective life of about 25 years. Exploration is being continued at depth, while on surface several promising indications of ore continue to be explored in the vicinity of the mine. Several other properties of the company are now being examined.

In the three months to March 31 last ROAN ANTELOPE COPPER MINES produced 22,061 tons of copper, the estimated profit for the period being £1,911,000, before providing for taxation. In similar terms MUFULIRA COPPER MINES produced 27,866 tons of copper for a profit of £2,536,000 and CHIBULUMA MINES 5,800 tons for £469,000.

Ghana.—ARISTON GOLD MINES (1929) reports a profit of £335,562 for the year ended September 30 last, the accounts showing £418,930 available, of which dividends equal to 6d. per stock unit require £147,656. In the year 467,915 tons of ore were milled, against 474,920 tons for the previous year, the total bullion revenue being £1,899,604, against £1,856,909. The ore reserves at September 30, 1959, were computed at 2,219,784 tons of an average value of 6·76 dwt., a decrease of 175,121 tons and of 0·01 dwt. in the average value as compared with the preceding year.

Nigeria.—The operations of EX-LANDS NIGERIA during 1959 resulted in a profit of £59,030. Of the £127,946 available a dividend equal to 20% requires £34,150. The output of tin concentrates was 467 tons, of which 409 tons constituted the permissible export quota.

Tanganyika Territory.—Shareholders of URUWIRA MINERALS have been informed that the company has received notice from the Tanganyika Government that it is not their intention to extend a guarantee given by them in respect of a loan of £350,000 due for repayment on April 30. The directors have confirmed to the Government its inability to repay the loan.

In the March quarter GEITA GOLD MINING milled 63,140 tons of ore and recovered 11,382 oz. of gold. The working profit for the period is given as £9,593.

Australia.—With the recent dividend notice shareholders of MOUNT ISA MINES were informed that it is intended to issue one new fully-paid stock unit of 5s. (Aust.) for every three held, for which purpose it is proposed to use the assets revaluation reserve and a portion of the stock premium account. A meeting to authorize this proposal was held in Brisbane earlier this month.

New Guinea.—In the three months to February 29 last BULOLO GOLD DREDGING treated 1,392,149 cu. yd. of ground and recovered 5,508 oz. of gold. The report for the period states that the production of SOUTH PACIFIC TIMBERS increased during the nine months ended February 29, the estimated net profit from the operations in New Guinea for the nine months being $355,000, after allowing for taxation payable on certain income in the Territory of New Guinea. In addition Bulolo Gold Dredging has received dividends from COMMONWEALTH-NEW GUINEA TIMBERS amounting to $354,800 (net after tax) and dividends from PLACER DEVELOPMENT of $50,300.

Malaya.—Last month the directors of TEKKA, LTD., announced that they had received an offer from GOPENG CONSOLIDATED to purchase the whole of the issued share capital of the company, with a view to merging interests. The terms of the offer are 2s. 6d. in cash for each Tekka share and three fully-paid stock units of 3s. 6d. each in Gopeng for every 10 shares of 12s. 6d. each in Tekka. The Tekka directors, it was stated, considered the proposals to be fair and reasonable and intended to recommend their acceptance.

Canada.—At the annual meeting of the INTERNATIONAL NICKEL CO. of CANADA held in Toronto last month shareholders approved a recommendation by the directors that the shares of the company be split on a two-for-one basis and that the resulting 30,000,000 shares be increased to 36,000,000 by the creation of 6,000,000 additional shares. At the meeting Dr. J. F. Thompson, the chairman, reviewed progress at the company's nickel development project at Thompson, Manitoba, where mine development had proceeded on schedule. Up to the year-end some 95,000 ft. of development advance had been driven. The 2,100-ft. production and the 1,100-ft. development shafts were connected at four levels, while development of stopes and other operations preparatory to mining are under way. During 1959 the mill building and the smelter building were completed, with the major portion of equipment installed. At the same time construction of the electrolytic refinery at Thompson had proceeded rapidly and production of electrolytically-refined nickel is scheduled for the first part of 1961.

General Tin Investments.—The net revenue of General Tin Investments, Ltd., and its subsidiary for 1959, subject to audit, is reported as £209,067 after providing £132,091 for taxation. Interim dividends totalling 12% (the same) were paid during the year and it is not intended to make any further distribution.

Union Corporation.—The consolidated accounts of the Union Corporation for the year ended December 31, 1959, show that after providing £830,119 for taxation there was a profit of £2,856,915, to which £1,291,593 brought forward from 1958 has to be added. After eliminating from the profits brought forward £145,523 attributable to a company which ceased to be a subsidiary during the year, there remains a total of £4,002,985, of which £2,005,521 has been retained by subsidiary companies, leaving £1,997,464 available for appropriation. It has been decided to write off note and new share issue expenses amounting to £3,232, and to place £150,000 to exploration reserve account, £300,000 to general reserve, and to declare a final dividend of 2s. 9d. There remains an unappropriated profit of £395,795 in the accounts of the corporation to which has to be added £805,521, being the unappropriated profits of subsidiary companies after the transfer of £1,200,000 to consolidated general reserve account, making a consolidated balance to be carried forward of £1,201,316.

DIVIDENDS DECLARED

* Interim. † Final.
(Less Tax unless otherwise stated)

Ariston Gold Mines (1929).—† 3d. and * 3d., payable May 31.
†**Bisichi Tin Co.**—6d., payable June 3.
Bralorne Pioneer Mines.—10 cents, payable Apr. 29.
†**Broken Hill South.**—4d. (Aust.), payable June 25.
†**Consolidated Zinc Corporation.**—2s. 9d., payable July 1.
†**Ex-Lands Nigeria.**—20%, payable May 20.
†**General Mining and Finance Corporation.**—5s., payable June 6.
***General Tin Investments.**—4%, payable May 13.
Globe and Phoenix Gold Mining.—† 20% and * 100%, payable May 24.
***Gopeng Consolidated.**—1½d. and 4½d., payable May 21.
International Nickel Co. of Canada.—Quarterly, 37½ cents (U.S.), payable June 20.
†**Killinghall Tin.**—1s. 3d., payable May 30.
***Lampa Mining Co.**—10%, payable June 1.
†**Loloma (Fiji) Gold Mines.**—6d. (Aust.) and 9d. (Aust.), tax free, payable July 8.
†**Mason and Barry.**—2s. 6id.
***Messina (Transvaal) Development Co.**—5s., payable July 6.
***Mount Isa Mines.**—6d. Aust., payable June 29.
†**New Broken Hill Consolidated.**—1s. 6d., free of tax, payable July 1.
†**North Broken Hill.**—2s. 6d. Aust., payable June 22.
†**Oceana Development Co.**—10%, payable May 31.
***Pahang Consolidated Co.**—3%, payable June 4.
***Pengkalen.**—3d., payable May 27.
Premier (Transvaal) Diamond Mining Co.—Pref. 12s. 6d., payable May 27.
†**Selayang Tin Dredging.**—25%, payable May 26.
***Sungei Way Dredging.**—5%, payable May 20.
***Tanganyika Concessions.**—1s. 6d.
***Tanjong Tin Dredging.**—7½d., payable May 14.
†**Tharsis Sulphur and Copper.**—12½%.
†**Union Minière du Haut-Katanga.**—Fr. 1,000, payable May 27.
†**Western Selection and Development Co.**—8%, payable June 20.

METAL PRICES

May 10.

Aluminium, Antimony, and Nickel per long ton; Chromium per lb.; Platinum per standard oz.; Gold and Silver per fine oz.; Wolfram per unit.

	£	s.	d.
Aluminium (Home)	186	0	0
Antimony (Eng. 99%)	190	0	0
Chromium (98%–99%)		7	2
Nickel (Home)	600	0	0
Platinum (Refined)	30	5	0
Silver		6	7⅛
Gold	12	10	1½
Wolfram (U.K.)		—	
(World)	7	8	6

Tin, Copper, Lead, Zinc } See Table, p. 312.

Mineral Processing in Review

An assessment of the main points raised during the recent Congress

E. J. Pryor, A.R.S.M., D.I.C., D.Sc., M.I.M.M.

The 1960 International Mineral Processing Congress held in London from April 6 to 9 at Church House, Westminster, established new records in these post-war events, the first of which was that sponsored by the Institution of Mining and Metallurgy in 1952. In the following year there was a similar gathering in Paris, while in 1955 Goslar, in the Harz, was the venue. By the date of the next Congress, that in Stockholm in 1958, the scale of events had grown further and when Lord Hailsham opened last month's proceedings he was able to note that most nations were represented by the several hundred delegates attending. It is evident from the 52 papers presented, and as the severely compressed discussions underlined, mineral dressing has to-day vindicated its right to be treated on its merits as a vital subject, whether at the fundamental levels recorded in the various fields of research or in the applications which take this scientific knowledge to the specialized techniques where the processing industries bring new treasures to the enrichment of living.

Proceedings opened with the fifth Sir Julius Wernher Lecture, delivered by Dr. I. W. Wark, a note on which appeared in the April issue of the MAGAZINE. Following this the Congress members and their ladies were received by the President of the Institution of Mining and Metallurgy, a pleasant "conditioning time" following. Serious work started on the following morning, the papers being taken in nine sessions, followed by a review session during which some authors made brief replies to points which had been raised. Here, as with all the discussions, time could only be given for a few speakers and these were for the most part rationed to a few minutes. Because of this limitation (unavoidable with such a wealth of material and expert commentators) any attempt to summarize the discussion of any paper adequately is impossible in the present article, which is designed to be of current interest. At the conclusion of proceedings M. Pierre Seyer announced that the next Congress would convene at Cannes in the spring of 1964. In London the weather gave us little temptation to play truant, but the French Riviera may test our strength of mind! The language problem this year was handled by the use of headphones which offered French, German, and Russian as alternatives to the official (English) tongue. The unequal length given to summaries of the papers in what follows is in no sense a reflection on the relative interests of their contents. Where a lengthy mathematical exposition is used, or the subject calls for a number of tables and graphs, condensation would not serve a useful purpose. In such cases a brief note directs the specializing reader to the main theme. The papers, together with their discussions, will in due course be officially published by the Institution.

Session I—Comminution (*Papers 1–5*)

With Dr. J. H. Watson in the chair the five papers forming the basis of discussion for the first session were introduced by Mr. D. J. Ottley.

In Paper 1, after extending du Pont's formula for power consumption to allow for charge density and mill length, Professor R. T. Hukki defines the *Base Mill* used to compared power requirements of a variety of mills (rod, tricone, ball, and pebble) by means of a power index. Given basic data which includes tonnage to be ground in a given time, number of grinding stages proposed, net energy for each stage, density of grinding medium, mill type and speed, it is possible to bring improved precision to the work of calculating size and power requirements.

Autogenous fine grinding is next considered in connexion with speeds in the sub-critical to super-critical speed range. A new form of mill design is outlined in which attrition grinding is expected to become of commercial interest, the heavy wear being

mainly directed on to the ore, by means of the retarding effect introduced by stationary braking weights suspended axially in the mill.

D. Weston next described the Aerofall mill and its grinding action. Diameter of these mills varies from 5 ft. to 22 ft. and feed up to 36 in. diameter is handled in one-pass treatment at a controlled product size from *minus* 4 mesh to 95% *minus* 200 mesh, the system being air-classified. Up to 18% moisture can be tolerated, thanks to the recirculation of 90% of the air, which has been heated during grinding. Since each particle produced in the mill is exposed to a preliminary stage of air classification within a second or two, liberation occurs at a coarser mesh than is practicable in wet grinding. Three further classification stages complete classification, for which high efficiency and circulating load are claimed. Comminution is due to impact crushing, abrasion, and zoning control of the crop load which, as shown in diagram form, moves in two distinctively sized paths. Peripheral lifters (crushing bars) and annular ridged liners produce a complex crushing action, with impact accelerated by the crushing bars which travel about 17 ft. per sec. Up to 2% of the mill volume can be charged with 5-in. to 5½-in. steel balls for crushing tough ore. Operating data are given in support of the claim to improved efficiency, economy, and metallurgical results, as compared with rod and pebble milling.

Paper No. 3 by B. Fagerberg and H. Ornstein describes grinding tests in a pilot plant in which two low-grade magnetite ores were treated in an Aerofall mill and also in dry and wet rod-mills. The final requirement is a coarse-grained concentrate assaying 60–65% Fe and the further point of interest is the possibility of using low-intensity dry magnetic concentration, which is preferable in some ways to wet treatment. A 5 ft. by 2 ft. Aerofall mill, autogenously loaded, was compared with a continuous laboratory rod mill 400 mm. in diameter and 800 mm. long. The work showed that in the Aerofall the ore tends to disintegrate along its grain boundaries at natural liberation mesh and gives much better liberation than the rod-mill. It is at its best on hard ore, when wear and power are below the comparable figures for rod-mills. A probable further saving would be elimination of multi-stage crushing. Somewhat better results were obtained from dry magnetic treatment of the Aerofall product, which contained less flocculating fines, since these are not usually found to be amenable to dry magnetic treatment.

Methods and equipment used in exploratory grinding tests in the laboratory under batch, open-circuit, and closed-circuit conditions were dealt with in Paper No. 4 by D. G. Armstrong. The purpose is to achieve a screen analysis of the ground product which is comparable with what could be obtained with a commercial system, due regard being had to the test work which is to follow comminution. The equipment includes an 8-in. diameter by 10-in. long batch mill and a 10 in. by 15 in. continuous mill with a drum feeder and, at the discharge end, a perforated plate, elevator and discharge throat, and trommel. The hydraulic classifier closing the circuit has an automatically-controlled pulsed spigot discharge to ensure a correct return pulp density. Tests gave reasonably good correlation between batch and open-circuit rod-milling, the resulting screen analyses being similar to those from large ball-mills. With change from rods to balls a very long-range product resulted and correlation between batch and continuous grinding was no longer good. The batch or the open-circuit ball-mill gives too wide a particle size range for practical use but open-circuit and batch rod milling is acceptable. These conclusions apply to homogeneous materials.

The last paper, by P. Westerlund, describes laboratory-scale tests made in a vertical grinding mill. This consists of two concentric cylinders between which ore and grinding media are fed, discharge being through a slot at the bottom. The mill can be worked wet or dry. Performance was compared with that of a conventional mill of similar dimensions, load, and speed, both fed with *minus* 2 *plus* 1-mm. ore. The ordinary mill (O) was used batchwise with pulp at 66·7% solids and the vertical (V) mill continuously at 60% solids. Feed rate to V was 7·5 times that for O and the size analysis was closer to that produced in the full-scale milling practice. The capacity of V was much higher than that of O in terms of kg. per hour and the new surface produced was also better, with reduced energy consumption per unit of weight ground. Comparative tests using rod-mill discharge as feed confirmed these findings Following these tests a larger mill was made, in which only the inner cylinder rotated. To decrease wear the shell surfaces were vertically ribbed, giving an autogenous lining. Feed was now introduced from below, the product overflowing to a collecting

launder. This gave some classification in the grinding zone. Test work is at its early stages, but promises well.

The author's conclusions are that capacity in a vertical mill is far higher, energy used comparable, attrition forced, cost low, and wear reasonable with autogenous media.

Session II—Classification and Thickening
(*Papers 6–10*)

For the second session Professor P. G. Kihlstedt was in the chair, the author performing the introduction of a topic mainly dealing with the movement of particles in water.

Paper No. 6, by Professor A. M. Gaudin and M. C. Fuerstenau, " On the Mechanism of Thickening," gave the conclusions reached as the result of an experimental and theoretical study of thickening. Using an X-ray absorption technique to scan changes in the opacity of a settling suspension over a vertical distance and automatically recording change and time in relation to this distance, settling conditions were co-ordinated with the ruling pulp density. The picture to emerge is a bimodal process equivalent to filtration. In the earlier stages this takes place through tubes in the relatively dilute suspension and continues indefinitely through " tubules." If observation begins with very dilute flocculated pulp a still earlier phase is free or hindered settlement, which is followed by the filtration stages as settlement *en masse* ensues. From consideration of the effect of the driving force—gravity—and its incidence in Poiseuille's Law, a mathematical model is discussed and equations are derived.

The design and performance of cyclone thickeners were dealt with in Paper No. 7 by D. Bradley, who is concerned primarily with the dewatering of dilute suspensions. He includes studies of variations in the flow rate, cone angle, and vortex finder shape and dimensions of a laboratory-scale appliance. Efficiency tests were made using a dilute slurry of closely-sized perspex spheres ($\frac{1}{2}$% solids) as test feed. From the work the author concludes that on empirical grounds the specification of a cyclone thickener plant can be drawn in the case of dilute feed slurries of approximately spherical particle shape, given standardization of design in line with the shape of the test apparatus found most efficient. Above a liquid/solid ratio of 8 : 1 hindered settling may affect performance and the reliability of the d_{50} equation proposed might be affected, d_{50} being the size of a particle equally likely to appear in overflow or underflow.

There followed a paper by C. G. Peachey, who studies the distribution between overflow and underflow of the water entering the cyclone. Tests commenced with a cyclone of conventional construction and, after varying the diameter of the vortex finder, with a separating plate only. Finally the shell of the appliance only was used, the bottom of the overflow port being $6\frac{5}{8}$ in. above the top of the feed in a 27-in. diameter cyclone 7 ft. 4 in. long. The author's conclusion is that for a given setting and feed the apex must accept a definite amount of *minus* 200-mesh product at a definite solid/liquid ratio or pulp viscosity (using the last word in its sense of specific surface). Since in this conclusion the *minus* 200-mesh material is underflowed with " top priority " the more of it there is the less *plus* 200-mesh material can pass, excess being forced to the overflow. This unorthodox view shifts the emphasis to hindered settlement to a degree which would appear to turn not only the sizing effect upside down but to extend this change to most of what is known of cyclone action.

In Paper No. 9 D. F. Kelsall and J. A. Holmes describe a development in cyclone construction which may, if it can be scaled up to plant size, lead to valuable improvements in grinding practice. Hydraulic water is injected toward the discharge end of the cone by various methods described and the effect on separation is shown by size analyses of the products. In one case injected water reduced the percentage of *minus* 10-μ material in the underflow from 43% to 11·5% and in another from 48·4% to 11·5% of the entrained slimes, these percentages referring to about a quarter of the feed solids passing down at *minus* 200 mesh. In a further series the effect of operation with and without injected water was measured with respect to overflow sizes. In a full-scale mill test injection changed the *minus* 325-mesh underflow from 7% to 2·8% and overflow from 63% to 59·4% with a circulating load of 350% and 160% respectively. The change in ball-mill discharge of its *minus* 325-mesh fraction was from 19·6% straight to 24·8% injected. The authors' general conclusion from these and other tests was that injection largely reduced the circulating load and that more test work may lead to " considerable overall benefits . . . in the field of closed-circuit grinding."

In the final contribution to this session

(Paper 10) Dr. G. Ferrara describes the study of an ore pulp as it flows through a rotating tube, the effects of the centrifugal separating forces thus generated being shown for a mixture of galena and limestone particles. A perspex tube 110 cm. long and of 2 cm. bore is mounted horizontally and rotated at speeds varied from 600 r.p.m. to 2,200 r.p.m. Particles in the pulp flowing along the tube are affected by their accelerated sedimentation rate due to centrifugal action. At entry from the stationary feed tube angular velocity is built up and there is a zone of tangential stress between the concentric layers. In the later (second) zone all the fluid rotates with the same angular velocity and these stresses disappear. Individual particles trace a spiral whose components are settling speed (product of size, rubbing area, and specific gravity) and flow rate (product of area and average cross-section). From the studies described the author concludes that the theoretical principle is in part confirmed by the early test work and that separation is substantially unaffected by particle size, so that an apparatus capable of treating a wide size-range may be practicable. Continuous discharge from the rotating tube is among the problems not yet satisfactorily solved.

Session III—Flotation Research

(*Papers 11–18*)

The chair at this session was taken by Professor A. M. Gaudin and the papers were introduced by Dr. M. G. Fleming. Of these papers five came from the U.S.S.R., where the vital role of mineral processing in modern industry has received more State encouragement than in the western world. The other three came from Canada, France, and Japan.

In Paper 11 a research team headed by Professor O. S. Bogdanov reports work on the kinetics of flotation reagent sorption. An adsorption column was used in which a relatively large volume of reagent, at specified concentration, flowed through a column of powdered mineral. The reagents were radioactive and techniques were developed by which the sorption value (as percentage of a monolayer) was correlated with concentration of xanthate in solution in a given time. By splitting the flow equally between two columns the effect on two minerals was also compared. It was found that the rate of interaction of xanthate with galena and of copper ions with sphalerite is linear in relation to the concentration of these ions in solution if the sorption layer forms only a fraction of the monolayer. Activation of sphalerite by copper ions was found to be a high-rate process, a virtually complete copper-ion monolayer being formed in 1 min., though linear correlation with rate is uncertain after 15% of the coating has been completed. The depressing effect of KCN was confirmed as being due to formation of a highly soluble $KCu(CN)_2$ complex, sorption of CN^- ion by mineral being negligible. Differential rates of complexing make it possible to separate chalcopyrite and sphalerite from, say, galena by use of $K_2Zn(CN)_4$ which films secondary copper mineral and the sphalerite with zinc ions, sorbed presumably as hydroxides. This slows down the dissolution of copper sulphide and causes stable depression and in the author's view therefore accounts for the superior efficiency of $K_2Zn(CN)_4$ over KCN in this type of separation.

In the next paper (12) Professor V. A. Glembotsky studies the physical stability of collector layers and the effect of various methods for their destruction, as a means of improving selective flotation of bulk concentrates. Among the methods described alone or in combination are ultrasonics, high temperature, electric current at various frequencies, and surface abrasion. Effects on adsorbed layers are determined by flotation tests, use of radioactive isotopes, and potentiometric titration. Bulk floats are usually broken down commercially by the use of dichromates for depressing lead from copper-lead, or cyanide for dropping the zinc from a galena-sphalerite concentrate. To study the conditions for stability of such materials as a first step in improving this type of operation normal bulk flotation was followed by application of one of the methods named to the concentrate prior to repetition of flotation. Using abrasive action of an impeller running in a solid/liquid pulp of 2 to 1 at a peripheral speed of 3 m./sec., galena was 37% depressed in 15 min. and 98% in 60 min. Action was less effective on finer sizes. It was much less effective with chalcopyrite and sphalerite and appears to depend on the mineral's resistance to mechanical abrasion. The steaming technique used to separate floating molybdenite from copper sulphides was studied for other minerals by the use of hot water, by high-frequency (induction heating) effects on dry concentrates, and by simple electrical current heating. Boiling water virtually "killed" galena in 10 min. and chalcopyrite in 2 min.

but sphalerite and pyrite (20% in 10 min.) were resistant. Passage of electric current through moist concentrates showed a similar trend. Live steam was less effective than hot water. A curious point is that galena ceases to float after 1½ min. to 2 min. of heating, during which only 5% to 7% of the xanthate decomposes. Potentiometric titration of filtrate from a galena concentrate which had been treated with hot water revealed absence of xanthate, though some 50% of the stably sorbed xanthate had returned to solution. It appears that aqueous xanthate decomposes far more slowly than adsorbed xanthate. Thermal treatment destroys the chemisorption bond between xanthate ion and crystal lattice of the sulphide galena.

Ultrasonic treatment showed that galena could be depressed from its bulk float with chalcopyrite; galena from sphalerite; pyrite from chalcopyrite.

Professor I. M. Plaksin then reported extensions in the use of micro-auto-radiography and allied techniques in the study of superficial layers of flotation reagents on minerals, also the interplay between mineral structure and reagent (Paper No. 13). The qualitative and quantitative distribution of reagent on both sulphides and non-sulphides were determined, together with their stability. Fixation of a reagent on a mineral particle in water depends on lattice structure and on features of its cleavage planes. As concentration of xanthate is increased, fixation also rises with formation of heterogeneous areas and multilayers. The electrochemical potential of a given species may vary greatly—*e.g.*, galena, between *minus* 0·20 and *minus* 0·75 V. Distribution of oxidation products on a newly-formed galena surface stored for a few hours under humid conditions is spotty. Electrochemical tests used cathodic and anodic polarization methods similar to those applied to the study of metallic corrosion. These yielded photo-micrographs of the cathodic areas on new galena surfaces. Such a heterogeneous surface varies in its aerophilic quality and chemical activity. In cathodic zones it is to be expected that the first cations to be fixed will be those of such low-solubility hydrates as Ca^{++}, Zn^{++}, Fe^{+++}. Xanthate fixation was studied using butyl xanthate tagged with radioactive S^{35}, freshly-cleaved mineral being made the electrode in a cell in which the 0·001% xanthate was agitated. Fixation is linear between voltages of *minus* 1·2 and 0 when it reaches $10 < 20\%$ and rises sharply from 0 to *plus* 0·8, being complete for galena at *plus* 0·2, for pyrite at *plus* 0·6, and for chalcopyrite at 0·8. Most of the xanthate is fixed on the anodic areas in the less accessible regions and hollows of the surface. It depends on the concentration of competing anions in the pulp (S^{--}, HS^{-}, etc.) which determine the electric force's field gradient between anodic and cathodic areas. Microscopic defects in crystals have considerable effect on chemical reaction. Pyrrhotite and sphalerite are notable examples of defective structure. Flotation tests on titanium and zirconium minerals showed that the kind of gas used affected selectivity. Nitrogen depressed TiO_2 from a bulk gravity concentrate from which 80% of the zircon floated at 68% after de-oxygenation.

Paper 14 by Professor M. A. Eigeles and M. L. Volova describes a kinetic method of investigating the adhesion of bubbles to mineral surfaces as affected by time, temperature, and surface condition. An apparatus for measuring or controlling contact time by means of an " electronic stop watch " giving automatic control between 0·001 sec. and 1 sec. is used. The bubble is held stationary in a cell of 5–6 $cm.^3$ capacity which is vertically moved by the automatic control. Events are scanned by an optical system which projects a magnified image of bubble action on a screen. The sample is of 1 gram. of particles and adhesion is considered to occur when more than $20 < 40\%$ of the particles at the contact area are left clinging when contact is broken. Induction time is much lower with smooth withdrawal than with accelerated retraction. This appears to be related to the speed with which the wetting film is thinned. Induction time is reduced, on collector addition, to about 2–3 millisec. Raising the pulp temperature to 50–55° C. still further reduces induction time, as does increase in concentration of collector. Changes in boundary chemical state and in viscosity probably promote more rapid thinning and growth of attraction forces.

In Paper 15 Professor M. Wada discusses the relationship between adsorption energy and wettability of solid surfaces by aqueous solutions of certain paraffin-compounded reagents. Three types of wetting isotherm are derived, for paraffin frothers, galena-xanthate, and quartz-dodecylammonium acetate respectively.

Work by Professor V. I. Klassen is outlined in Paper 16. He studies bubble formation in the flotation process and develops equations which show that oversaturation of

the pulp by the flotation gas leads to instantaneous development of bubbles in accordance with frother concentration and hydrophobicity of particle surface at places where molecular coupling is weak. Addition of a frother facilitates precipitation of dissolved gases and reduces bubble size. It is more difficult to form a cavity in water than at a solid-liquid interface since the dipole attraction is much greater in the former case. Vacuum flotation, by raising the supersaturation, improves this bubble production. Possibilities of better flotation of mineral below 10 μ is suggested as the result of better understanding of gas precipitation, which removes the difficulty of ensuring the collision of such fine material with air bubbles coursing in the pulp. Selective bubble formation is initiated on preferred particle surfaces by gas precipitation and coalescence. Growth and binding into bubbles follows more readily.

Next, Paper 17 by Dr. J. Leja and G. W. Poling deals with the interpretation of contact angle. A modification to Young's equation is put forward which compensates gravitational effects in large bubbles or at threshold cling. Then, in Paper 18 Professor M. Rey and V. Formanek outline results thus far obtained in investigating the factors which affect selective separation of lead from zinc, notably during flotation of oxidized lead ores. The purpose of the research was to find the reasons for the large differences in selectivity and to find methods for improved treatment. The situation was found more complex than had been expected but some conclusions were reached. *First*, sphalerite floats with only a frother when ground in a porcelain mill or in the presence of a silica gangue. Limestone, sodium carbonate, and metallic iron all suppress this natural floatability. *Second*, when comparing grinding in different mills before flotation with xanthate, galena is depressed by iron and not by porcelain. Aerofloat is less sensitive. Pebble milling ahead of a collective lead-zinc float is an interesting possibility. *Third*, sphalerite is activated by lead minerals—slightly by galena, moderately by cerussite, and strongly by anglesite, an effect not suppressed by sodium carbonate. *Fourth*, iron abraded during grinding has a strong de-activating effect with silica gangue and mild with limestone. It varies with the type of iron alloy used in liners or balls. *Fifth*, zinc powder has a similar effect but aluminium and magnesium have not. *Sixth*, calcium sulphate improves selectivity with a silica gangue but lowers recovery of lead. Summarizing their work, the authors conclude " that lead-zinc selectivity is strongly influenced by the mineralogy of the ore, including the gangue and the soluble salts, and by the type of grind and that all zinc depressants known so far have only moderate effects.

(To be concluded)

Vacuum Metallurgy

W. H. Dennis, B.Sc., M.I.M.M.

Techniques increasing in new application are reviewed

Introduction

The advent of atomic energy, electronics, and jet-engine manufacture has led to a demand for metals and alloys of a very high order of purity and this has necessitated the development of new operational techniques. Among these the application of vacuum to metallurgy has now become well established and is rapidly increasing.

Many metals when melted in contact with air pick up oxygen, hydrogen, and nitrogen, with deleterious effect on the strength and other required properties, especially when the metal is stressed at high temperatures, as in steam turbines and jet engines. The liability to gaseous contamination also introduces complications in subsequent operations such as casting, annealing, and forging. The harmful effects of these gases is due in many

instances to the fact that their generally higher solubility in the molten metal as compared to the solid state results in supersaturation which on cooling causes precipitation at the grain boundaries of the metal crystal. These crystal boundary inclusions result in embrittlement of the material, with consequent deterioration and even failure in service. Further, if a melt has gas in solution, then on solidification of the cast metal the gas in excess of the solubility limit will be evolved and produce blow holes with consequent blistering of sheet material. The solubility of the gases oxygen, nitrogen, or hydrogen in molten metal is proportional to the square root of the partial pressure of the gas over the melt. It is thus apparent that the gas in solution may be reduced by a reduction in pressure.

The avoidance of any reaction between the metals and the surrounding gas can thus only be prevented when melting is carried out either in vacuum or in an inert atmosphere provided by such gases as argon or helium. Powder metallurgical techniques, by means of which powdered metals moulded to the required shape are subjected to high pressures and temperatures, are, it is true, available for the shaping of many of the reactive metals, but the advantage of vacuum technology is that much larger quantities can be handled than is possible by powder metallurgy, which in general is confined to the production of small compacts. The use of vacuum technology has been especially rapid in its application to the "new" metals, for in general these are gas-sensitive to a marked degree. Pure uranium, thorium, and zirconium are produced by vacuum methods for use in atomic reactors. Vacuum furnaces are also used for the processing of ductile titanium, tantalum, molybdenum, and special steel alloys for jet and turbine engine parts. The electronic industry depends on the use of high-purity vacuum-treated germanium and silicon.

In addition to the new metals, vacuum treatment is also being increasingly applied to the older metals. Thus the vacuum casting of copper avoids the embrittlement effects of dissolved oxygen and hydrogen which is noticeable when drawing into thin wire. The degassing of steel and its alloys under vacuum results in greater strength and corrosion resistance and the recent application of vacuum to the diecasting process leads to sounder metal and a fall in the number of rejects. The recovery of magnesium from its ores by vacuum distillation dates from the last war and the process has now been applied to the production of other metals—such as, calcium, barium, and strontium.

The demand for vacuum-treated metals and alloys with special and improved mechanical properties has necessitated the development of operational pressures in the micron range (1 micron $= 10^{-3}$ mm. of mercury). The achievement of such low pressures on an industrial scale has only been made possible during the past few years by the development of suitable equipment designed to cope with the problems of withstanding low pressures and of pumping the large quantities of gas encountered in high-vacuum melting.

Production Equipment

The three essential requirements in any vacuum melting system are pumps, a heating source, and a vacuum chamber or process vessel containing the furnace assembly. The many details involved in the development of the process are all related to these three main features.

Pumps.

The primary considerations in a vacuum pumping system are the pressure range to be covered and the gas load. The pressure range is determined by a consideration of the lowest preliminary pressure to which the process chamber must be evacuated before the actual operation commences, in order that contamination resulting from the residual gases in the chamber should be below a tolerable figure. This requirement determines the ultimate vacuum necessary in the pumping system. Normally the pressure range for vacuum metallurgical processes is approximately 10 mm. to 10^{-6} mm. Hg. although for the majority of industrial application the lower limit is 10^{-4} mm.

Many vacuum processes are accompanied by the evolution of large quantities of gas and thus it is necessary to take into account the volume of gas that has to be removed in relation to the pumping speed of the vacuum pumping system. As various pumps develop their best performance over different pressure ranges and gas volumes it is usual practice to use a combination of pumps. In general a mechanical type of pump is preferred for the preliminary or roughing operation, in which the process begins. At this stage a vapour diffusion pump better suited to maintain

vacuum at a low pressure takes over, and normally begins to operate below a certain limiting pressure.

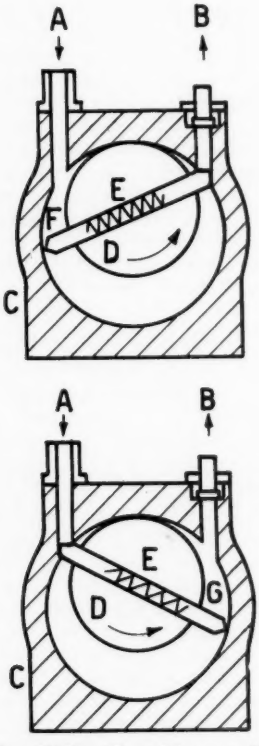

Fig. 1.—Sliding Vane Vacuum Pump.

A, gas inlet port ; B, gas outlet valve ; C, stator ; D, rotor ; E, spring loaded vanes ; F, vacuum side, and G, compression side.

Mechanical Pumps.—These are generally of the rotary type and consist of two main designs—(1) the rotary vane type and (2) eccentric piston type.

The former consists of a stationary casing in which a motor-driven rotor revolves in close contact with the stator. Protruding from the rotor are two vanes (Fig. 1) separated by a spring, causing the vanes to press tightly against the inner surface of the stator. During rotation the vanes sweep continuously round the stator carrying with them the gas taken in from the inlet port, which is then expelled out of the pump through the outlet pressure valve. Oil is present to lubricate the moving parts and to act as a seal.

The eccentric piston type (Fig. 2) consists of a rotor which rotates eccentrically within the stator and maintains an oil seal with the stator about a revolving axis. Protruding from the rotor is a hollow piston oscillating in a ball joint. Gas is taken in at low pressure from the vacuum system through the hollow piston, being compressed by the rotor to atmospheric pressure and then ejected through the outlet port. The whole unit is usually immersed in oil to prevent air leakage. If water or any other condensable vapour is contained in the gas being evacuated it will condense during the compression cycle and mix with the oil leading to a deterioration in the performance of the pump. In order to neutralize this effect

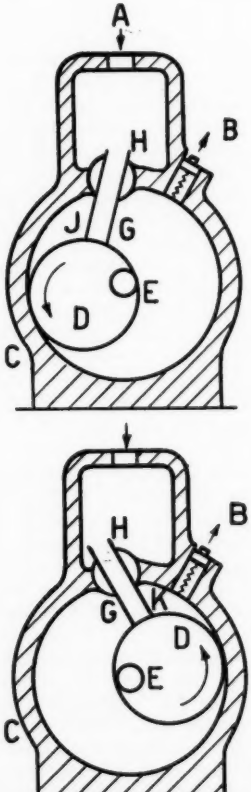

Fig. 2.—Eccentric Piston Pump.

A, gas inlet port ; B, gas outlet valve ; C, stator ; D, rotor, rotating eccentrically about E, revolving axis ; G, hollow piston ; H, ball joint ; J, vacuum side, and K, compression side.

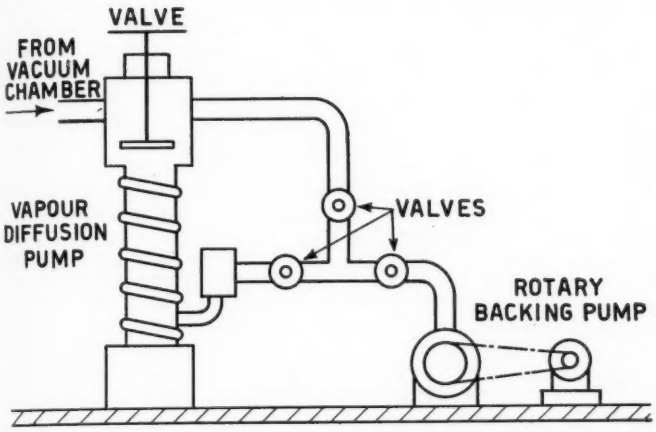

Fig. 3.—High Vacuum System.

atmospheric air in controlled amounts is injected into the gas during the compression cycle. This enables atmospheric pressure to be reached before the partial pressure of the condensable vapour has exceeded its saturation value at the temperature prevailing inside the pump. The technique known as "gas-ballasting" results in a slight deterioration of pump performance. Mechnical pumps are capable of an ultimate pressure of 10^{-2} mm. Hg and a displacement of up to 20,000 litres/min. of air.

Although mechanical pumps of the type described perform an extremely useful service in vacuum technology they suffer from several limitations. Friction caused by contact between the rotary and stationary mechanisms lead to appreciable wear and tear of the parts concerned. Efficiency of the pumps tails off in the region of 10^{-1} mm. Hg, and in general the pumps cannot be used to produce high vacuum in the region of 10^{-3} mm. Deterioration of performance where oil contamination is likely has already been mentioned. When large volumes of gas at pressures less than 10^{-3} mm. are required to be evacuated rotary pumps are inadequate and a type known as the vapour (diffusion) pump has to be employed. Although capable of producing and maintaining a vacuum as low as 10^{-6} mm. Hg, diffusion pumps do not evacuate directly from atmospheric pressure but operate in conjunction with a backing or fore pump of the oil-sealed mechanical type described above, which usually runs in tandem with the high-vacuum pump (Fig. 3).

Primary evacuation down to 0·5 mm. is thus first carried out *via* the mechanical pump, the high-vacuum pump then taking over and maintaining the vacuum at the required levels, delivering the gas extracted from the vacuum chamber to the inlet side of the fore pump which then ejects it to the atmosphere.

Diffusion or Vapour Pumps.—Diffusion pumps (Fig. 4) operate by the entrainment of gas in a vapour stream. An organic liquid or

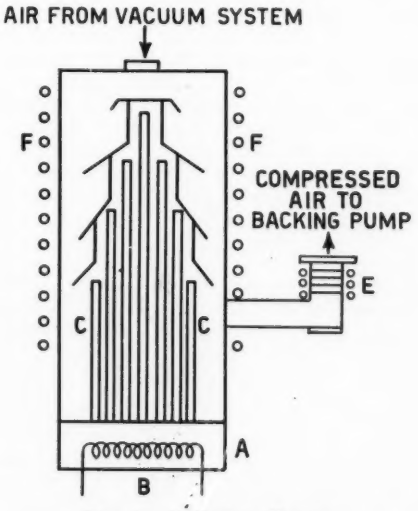

Fig. 4.—Diffusion Pump.

A, boiler for vaporizing pump oil; B, electric heater; C, vapour tubes; D, baffles; E, outlet baffles, and F, water cooling coils.

a silicone oil is evaporated in a boiler at the bottom of the pump. The vapour passes upwards through tubes discharging through nozzles, being dirceted by baffles on to the cooled walls of the pump upon which it condenses. The gas molecules being evacuated diffuse with the vapour stream and eventually arrive at the inlet side of the fore pump and from there are ejected to the atmosphere. The ultimate vacuum that can be obtained depends on the vapour pressure of the operating fluid which condenses on that part of the pump wall nearest the vacuum system and on the temperature of this wall. Water cooling is thus provided to keep the temperature as low as possible. These pumps have speeds of up to 15,000 litres/sec. at 10^{-4} mm. Hg.

Vapour Booster Pump. — The vapour booster pump was developed for industrial vacuum processes in order to combine, within the one pump, the high speeds of the vapour-diffusion pump with the high critical backing pressures of the vapour-ejector pump. The pump was further developed to maintain its high pumping speeds at far greater pressures than those normally associated with diffusion pumps—namely, 10^{-3} mm. These characteristics are of value in a process cycle required to end with a relatively-low ultimate pressure, but where initially-large volumes of gas have to be dealt with at pressures that would render the normal diffusion pump inoperative. An important feature of the vapour booster pump is that it is quite insensitive to wide variations in backing pressure, so that a considerable deterioration in the performance of the rotary pump makes little difference to the process times achieved, even though the process involves materials that contaminate the rotary-pump oil. The booster pump is able to eject to the rotary pump nearly all vapour contaminants and to maintain its high performance at low pressures. It is this ruggedness that accounts largely for its success in numerous industrial vacuum metallurgical applications during recent years.

The pump operates on the steam ejection principle, an oil vapour at high pressure being allowed to expand through a jet (Fig. 5). The gas from the system to be evacuated is entrained in the rapidly-moving vapour stream and passes to a baffle chamber which clears the gas from the oil, the former discharging to a backing pump, the condensed oil returning to the boiler. A chlorinated diphenyl type of oil is commonly used as the operating fluid as this has been found to be resistant to oxidation and decomposition at the boiler temperature. One obvious advantage of vapour pumps is that having no moving parts, operation is particularly simple and trouble free.

Heat Source.

The utilization of electricity as a source of heat is practically universal in vacuum technology, the reasons being : (1) Regulation of temperature is much more under control ; (2) rapid melting of the charge can be effected ; (3) no possibility of gaseous contamination of the charge from furnace gases, a danger which is always present when gas or

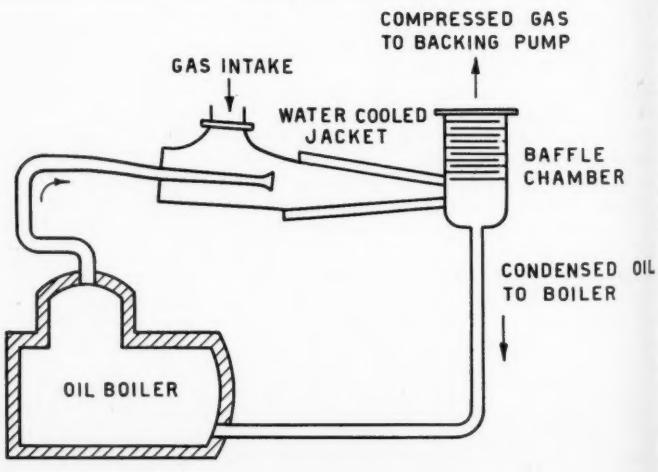

Fig. 5.—Vapour Booster Pump.

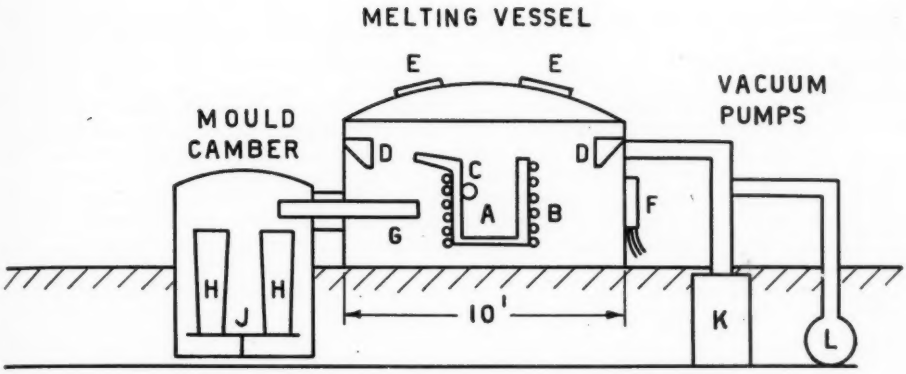

Fig. 6.—Vacuum Induction Furnace and Ingot Mould Chamber.

A, crucible; B, induction coils; C, tilting trunnion; D, charging buckets; E, observation window, F, H.F. cables; G, refractory launder; H, ingot moulds; J, revolving turntable; K, vapour pump, and L, rotary pump.

oil is used as fuel, and (4) as electrical heating usually involves the generation of heat in the metal itself contamination from the crucible material is avoided as the temperature of the latter is lower than that of the metal being melted.

The two types of electric furnaces in general use for melting are induction and arc. Electrical resistance heating has limited application in melting and casting of metals in vacuum, although it is achieving some prominence in such vacuum heat-treating operations as annealing, sintering, and brazing.

Induction.—The induction furnace consists of a refractory-lined crucible surrounded by water-cooled copper piping which constitutes the primary coil. Alternating current of high frequency is applied to the coil which induces secondary currents in the metal charge contained in the crucible, the resistance of the metal to the flow of current resulting in the production of heat which melts the metal. An interesting feature is that due to electro-magnetic action a stirring action is imparted to the molten metal, causing it to circulate continuously throughout the crucible, which is advantageous in giving uniformity to the melt.

Arc.—Discovery of the principle that metals with high melting point and gas sensitivity could be successfully arc melted in water-cooled copper crucibles greatly facilitated the metallurgy of many of the new metals. Indeed the production of pure titanium, zirconium, niobium, and molybdenum, which are all gas sensitive to a high degree and react with most refractory containers, could not have been achieved without this method of melting.

In essence arc melting can be likened to progressive welding, the arc being struck between a vertical electrode and the metal. The basic characteristics consist of: (1) An electrode connected to the negative pole of a d.c. generator which conducts the current into the furnace, the heat necessary for fusion being produced by means of an electric arc struck between the electrode and the metal to be melted. (2) A means of feeding the metal to the furnace. (3) A water-cooled copper crucible connected to the positive pole of the generator in which the metal is melted. (4) Provision for the production of a vacuum or an inert gas atmosphere.

According to the manner in which the metal is fed to the furnace two types of vacuum arc furnace can be distinguished. In the non-consumable type the electrode is of a permanent nature being constructed of graphite or tungsten, the metal to be melted being contained in the crucible. The consumable type of furnace employs an electrode composed of the metal to be melted held in a feeding device, the electrode being fed uninterruptedly to the arc until an ingot of predetermined size is attained.

Comparing the two types of arc furnace it has been found in practice that the melting rate of the consumable electrode type is about double that of the non-consumable type and also that the energy cost is lower. Further the use of a graphite or tungsten

electrode is liable to produce contamination of the metal to be melted. These factors account for the more widespread use of the consumable-electrode type of melting.

Processing Equipment

The type of vacuum chamber and ancilliary equipment employed in any particular process is necessarily governed by operational requirements and these differ to such a marked degree that no single description will suffice. The equipment is thus best considered in relation to the main metallurgical application of vacuum processing.

Applications

These are best discussed under four main headings: (1) Vacuum induction melting; (2) vacuum arc melting; (3) vacuum heat treating, and (4) vacuum distillation.

Induction Vacuum Melting.—This method (I.V.M.) is the only process used on any sizable scale for melting steels and its alloys. The use of vacuum removes dissolved gases and volatile impurities from the melt, reduces metal oxides by the carbon-oxygen reaction occuring at low pressures, and eliminates the effects of atmospheric contamination. The result of these conditions is a metal of consistently high quality with an accurately controlled composition.

The equipment employs a H.F. induction unit with a zirconium or magnesium refractory crucible so arranged that it can be tilted and made to pour the molten metal into ingot moulds. The welded-steel chamber containing the crucible assembly is mounted vertically (Fig. 6) and is closed by a lid formed from pressed dished ends to resist effectively the combined effects of water and atmospheric pressure. Both chamber and lid are usually double jacketed for water cooling. Observation windows are fitted in the lid. Temperature is determined by means of immersion pyrometers, while pressure measurement from 5×10^{-3} mm. Hg to 10 mm. Hg is covered by a thermal-conductivity type of gauge and a cathode ionization gauge for pressures below 5×10^{-3} mm. Hg. An evacuation port on the side of the chamber connects to a vacuum pumping combination which normally comprises a vapour booster pump working in conjunction with an air-ballasted rotary mechanical pump.

Special consideration is given to the problem of charging make-up and alloy additions, since where complicated alloys are required to be made it is desirable that the capacity of the charging system should be at least half the total capacity of the melt. The charging system uses a system of buckets which travel on the inner periphery of the vacuum chamber and are constructed with drop-away flaps that are released by the action of a transfer chute when charging the crucible; the operator is informed which bucket is in the charging position by an indicator on a selecting mechanism. Pre-

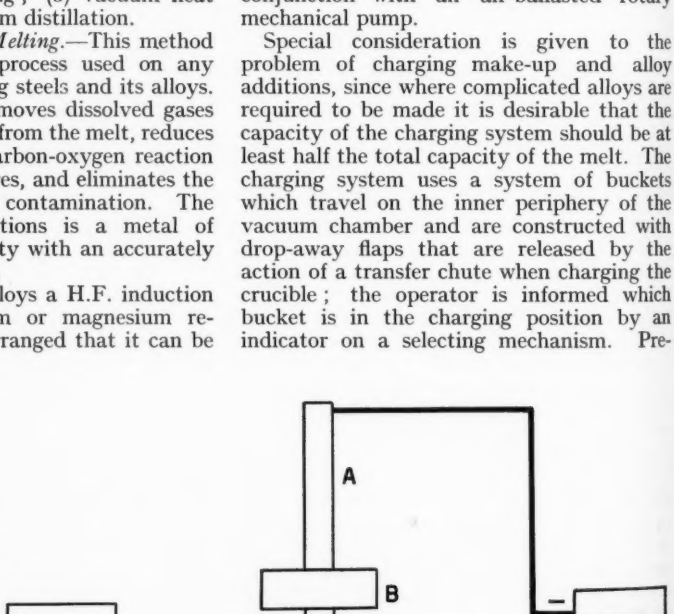

Fig. 7.—Consumable Electrode Furnace.

A, consumable electrode; B, electrode feeding device; C, furnace; D, water-cooled copper crucible; E, water inlet; F, water outlet; G, metal ingot; H, removable base plate.

selection may be made on this system, which is designed for random operation to give maximum flexibility during the melting operation.

To meet the stringent demands for many alloy specifications casting at normal pressure due to the danger of atmospheric pick-up has to be avoided and provision has to be made for casting under vacuum. This usually takes the form of a second chamber containing the moulds mounted on a bogey. The main vacuum chamber and the casting chamber are interconnected by a pipe which contains a refractory runner for conveying the liquid metal to the ingot moulds during casting.

In operation the raw material is charged to the furnace and the power applied. When molten the chamber lid is placed in position and evacuation begins. Once molten it is only necessary to supply power to compensate for heat losses and to provide adequate stirring of the melt to promote degassing and solution of the alloy additions. On completion of the melt the mould chamber is evacuated and the induction furnace tilted, the molten metal flowing to the ingot mould. At the end of the casting operation the vacuum to the casting chamber is broken, the bogey moved out on its rail track, the moulds removed and replaced with fresh moulds, and the process repeated.

In this country most ingots are of 1 cwt. or so, but in America ¼-ton and ½-ton ingots are more usual and ingots weighing as much as 3 tons have been melted and cast in vacuum.

The benefits obtained by induction vacuum melting of steel and alloys are due chiefly to the elimination of gases—hydrogen, for instance, can be reduced to 2 or 3 parts per million as compared to 16–20 p.p.m. by air melting. This eliminates the necessity to remove hydrogen by long and costly heat treatments in order to avoid " hair " cracking. Nitrogen is reduced down to 50 p.p.m. resulting in the avoidance of embrittlement. Creep rupture strength and fatigue resistance also improve. In addition to improvement to mechanical properties I.V.M. also affords close control of composition and homogeneity in composition. It is perhaps necessary to add that the tonnage of vacuum-treated steel as compared to that produced by conventional methods is at present very small. At the moment there are few commercial vacuum melting units of any size in this country, but the advantages outlined above cannot be ignored by the steel-making industry.

Vacuum Arc Melting.—This type of melting at present affords the only suitable procedure for the melting and casting of the gas-sensitive metals titanium, zirconium, and hafnium, and also forms a stage in the production of many other refractory metals. The method has also been applied to the production of steel and heat-resisting alloys. The consumable-electrode arc furnace (Fig. 7) consists of a vacuum-tight metal structure enclosing a water-cooled copper hearth or mould connected to the positive pole of the power source. A coil is wound round the outside of the water-jacketed hearth so that on the passage of a small current a suitable magnetic field is obtained which secures mixing of the molten metal and stabilization of the arc. The metal to be melted is briquetted in a press, the briquettes being welded together under argon to form round or square-shaped electrodes. The electrode is advanced by a system of gears external to the furnace and usually remote controlled to ensure safe working. In operation the furnace is evacuated and an arc struck by lowering the electrode to make contact with a plug of metal in the crucible. Current is then adjusted to the operating value which may be 3,000 amps. at 45 V. Under the extreme heat obtained from the arc the electrode metal melts and passes to the ingot mould, in the form of a fine spray, in which it condenses. Melting proceeds at a rate of up to 75 lb./min. in a 20-in. diameter furnace, ingots up to 2,400 lb. weight being produced. Owing to the high thermal conductivity of copper melting temperatures as high as 3,500° C. can be achieved without contamination of the molten metal with copper. Upon solidification shrinkage of the metal away from the side of the crucible enables easy removal of the ingot.

Vacuum Heat Treatment.—Another sphere in which vacuum treatment is gaining ground is the heat treatment of metal components. When atmospheric annealing of metals is necessary for such purposes as softening before cold rolling and wire drawing oxide scale is frequently formed on many metals causing waste of material and rough finish. Avoidance of these nuisances can be overcome by annealing in the presence of an inert gas, but vacuum provides a better and cheaper method. The vacuum annealing of stainless steels, titanium, zirconium, and uranium now results in improved mechanical properties with a good surface finish and with the virtual elimination of rejects. The continuous vacuum annealing of strip is

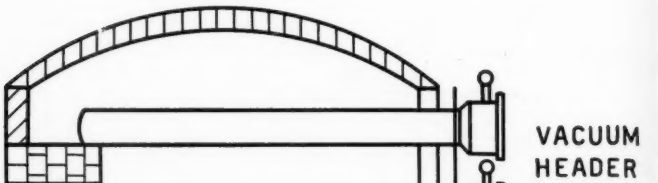

Fig. 8.—Retort Furnace for Magnesium.

made possible by the provision of vacuum-tight rolls and liquid seals.

Vacuum sintering is applied to nickel alloys, cermets, beryllium, tungsten carbide tool tips, etc., the operation being carried out in a high-frequency furnace designed for high vacuum and controlled atmosphere sintering to temperatures in the region of 2,500° C.

Vacuum Diecasting.—Diecasting is a method of mass-producing a large number of small articles by forcing molten metal into a closed die by means of a piston, the solid casting then being automatically ejected from the die. Air is frequently trapped as the metal advances in the die which shows up in the finished product as superficial blemishes and blow-holes. A solution to this outstanding problem of preventing unsoundness in the metal has recently been found by the application of a vacuum to the die cavity whereby the source of the trouble is removed. It is not unusual for rejects to fall from 15% to 2% when the equipment is turned over to vacuum diecasting.

Vacuum Distillation.—Although magnesium and the alkaline earth metals barium, strontium, and calcium are in general prepared by electrolytic methods yet large tonnages have been produced for several years in the vacuum furnace by reduction of their respective oxides. The method offers the advantage of relatively low operational and capital costs and a simple flow-sheet. The disadvantage of the process lies in the fact that it is a batch process and has not made much headway in face of the competing electrolytic process which is a continuous method.

Vacuum thermic methods take advantage of the fact that, on heating the oxide of the appropriate metal with a reducing agent under reduced pressure, the metal distils over and can be collected. The reducing agent in the case of magnesium is ferro-silicon ($2MgO + FeSi = SiO_2\ Fe + 2Mg$), aluminium being used with the alkaline earth metal oxides ($3CaO + 2Al = Al_2O_3 + 3Ca$).

The process is carried out by mixing the oxide with the reducing agent, briquetting, and loading into nichrome steel retorts supported in a horizontal position (Fig. 8) inside an electric resistance or gas-fired furnace. The retorts which are approximately 10 ft. long by 1 ft. diameter are fitted with a detachable sleeve which projects from the furnace and to which a vacuum header is connected. The furnaces are heated to a temperature of 1,000° C., the retorts being exhausted to a vacuum of 0·1 mm. The metal distils over and condenses in the cool end of the retort. The vacuum is then broken, the covers removed, and the metal unloaded. The red-hot residue is raked out and conveyed to the dump; operational temperature and control of vacuum is largely automatic, secured by the use of recording and regulating instruments.

A further application of vacuum processing in non-ferrous extractive metallurgy is to be found in lead refining. Lead from the blast-furnace smelting operation invariably contains impurities—such as, copper, antimony, tin, arsenic, bismuth, and sulphur, as well as the precious metal silver. Since these impurities adversely affect the properties of the metal their elimination is an economic necessity. Copper, antimony, tin, and arsenic are removed from the molten lead by a series of drossing and oxidizing operations. Next

comes the removal of silver. This is based on two facts—first, silver combines more readily with zinc than with lead and, secondly, zinc-silver alloys are insoluble in lead. Thus, by the addition of zinc, silver may be made to leave the lead bullion and combine with zinc. The latter metal is added in sufficient quantity to saturate the lead at the temperature of operation (400° C.) and provide an excess to combine with the silver. Crusts rich in silver are formed and are removed for recovery of the precious metal. The residual lead contains 0·4% to 0·6% zinc and its elimination is secured by a process known as vacuum de-zincing. The de-silverized lead is heated to just above its melting point and a large steel bell-shaped apparatus attached to a vacuum pump is submerged in the molten lead. The temperature is raised and zinc distills from the lead and condenses on the interior surface of the bell. After a suitable interval of time the vacuum is shut off and the bell removed, leaving the lead in a zinc-free condition. The zinc in the steel bell is collected and re-used in the de-silverization process.

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Mineral Identification Using Solid Reagents

K. F. G. Hosking, M.Sc., Ph.D., A.M.I.M.M.

Tests using a technique developed in the U.S.S.R. are described

Synopsis

Often the identification of a given mineral may be facilitated by grinding a little of the specimen directly—or after it has been decomposed by simple chemical means—with a small quantity of a solid reagent with which it reacts to form a characteristically-coloured substance. Tests of this type—which have been developed almost exclusively by the Russians, and which are not generally known in English-speaking countries—are described.

Introduction

From time to time details appear in *Analytical Abstracts* of a test for one or another of the elements in minerals which depends, essentially, on grinding a small portion of the specimen directly—or after the powder has been decomposed by a simple and rapid chemical method—with a solid reagent with which the element in question forms a characteristically-coloured substance. Almost invariably these tests have been developed by Russians and although they are powerful aids to mineral identification, and a French translation of Isakov's (1955) text on the subject is available (see Pietresson de Saint-Aubin and Jedwab, 1956), they are not generally familiar to mineralogists in English-speaking countries.[1]

In the present paper the writer outlines the fundamentals of this analytical technique and gives details of a number of the tests which he has found particularly useful. Needless to say, much of the material contained herein has been culled from Isakov's work (*op. cit.*).

Fundamentals of the Technique

Many minerals react with surprising rapidity with solid reagents when the two are ground together. This is probably due not only to the development of fresh highly-reactive edges and corners, and the partial disruption of the crystal lattices,[2] but also to the heat of friction and the transient

[1] A list of references is given at the end of the article.

[2] KOVALEV, G. A. (*Mem. All-Union Min. Soc. Russia*, 1957, **86**, 401–403) has demonstrated that dry grinding of minerals leads to partial or complete disappearance of lines on the X-ray powder photographs.

but high pressure to which the system is subjected during comminution. Absorbed water is also, doubtless, important.

Although most grinding tests depend for their success on double decomposition—as, for example, when cobalt is detected in, say, bieberite by the intense blue which appears when the mineral is ground with potassium thiocyanate :—

$$CoSO_4 + 4KCNS = \underset{\text{(blue)}}{K_2Co(CNS)_4} + K_2SO_4)—$$

reactions of combination and decomposition are also occasionally used. Thus, the identification of powdered silver is facilitated by grinding it with sulphur, as the two elements combine to form black silver sulphide. On the other hand, when green copper carbonate is ground in air it decomposes in a characteristic way to black cupric oxide and carbon dioxide.

Many minerals, however, have to be subjected to a preliminary chemical attack before grinding tests can be employed successfully. Usually this preliminary treatment either involves grinding with potassium bisulphate, or fusion with either an ammonium salt or a mixture of ammonium salts, but on occasion decomposition is effected by grinding with iodine. Generally the most effective reagent with which to fuse the sample to decompose it is " solid aqua-regia." [1]

In practice one or two small fragments—each not above 0·1 mm. long—of the mineral under test (which may on occasion be best selected under the binocular microscope or with the aid of a hand lens) are ground with about the same volume of the " colour-generating " reagent in a depression in a porcelain spot plate (or on a porcelain crucible lid) by means of a glass pestle 6 cm. long and about 0·6 cm. in diameter. *Unless very small quantities of the test substance and the reagent are used the all-important colour of the reaction product may be obscured.* Often the final colour may be enhanced, either by breathing on the ground mixture or by adding one or two small drops of water to it.

[1] Solid aqua-regia is prepared as follows :—One part (by weight) of ammonium chloride is well mixed with 2·5 parts of ammonium nitrate. The mixture is gently heated in a porcelain crucible until fusion is complete; then it is allowed to cool and is stored in a glass container. This " cake " is very convenient for field work as it is non-hygroscopic and relatively stable.

Normally preliminary fusions are carried out in small test tubes or porcelain micro-crucibles, but, when working in the field and whenever the quantity of mineral available for examination is severely limited, fusion is usually best effected in a thin-walled, right-angled capillary tube of internal diameter about 1–1·5 mm., which has one arm 10 cm. long and the other only approximately 1 mm. The shorter arm is charged by plunging it first into the powdered flux and then on to the fragment to be examined so that the latter becomes embedded in the flux. The mixture is heated for about 30 sec. in the flame of an alcohol lamp, or even by the flame from a match. Sometimes fusion may be achieved simply by focusing the sun's rays on to the charge by means of a lens. After fusion the cooled charge is extracted by the aid of a needle or a thin glass rod and ground on a plate with the appropriate reagent.

As in most analytical procedures the influence of interfering elements is overcome by complexing them or by converting them to a valency state in which they will not participate in the particular reaction. Thus, if a mixture of ferrous and cobaltous sulphates is ground with ammonium thiocyanate, a reddish colour appears which is due to the development of ferric thiocyanate. If then the ferric ions are reduced by grinding a little sodium thiosulphate into the mixture the red colour is destroyed and the intense blue of the cobalt-containing complex anion $[Co(CNS)_4]$, is seen.

Frequently, however, some or all of the elements which cause serious interference when a given test is carried out in solution may be ignored when virtually the same test is effected by grinding the solid components together. For example, as both nickel and ferrous ions form red complexes with dimethylglyoxime in ammoniacal solution the ferrous ions must be removed before testing for nickel. However, of the two elements in question, only nickel forms a red complex when a solid is ground with dimethylglyoxime.

According to Isakov (*op. cit.*) those elements such as osmium, selenium, and ruthenium, which form volatile compounds are best detected, not by grinding with reagents, but by allowing the volatile compounds to react directly with specific colour-forming reagents, for by so doing difficulties due to interfering elements are virtually eliminated. Thus, to detect selenium in a

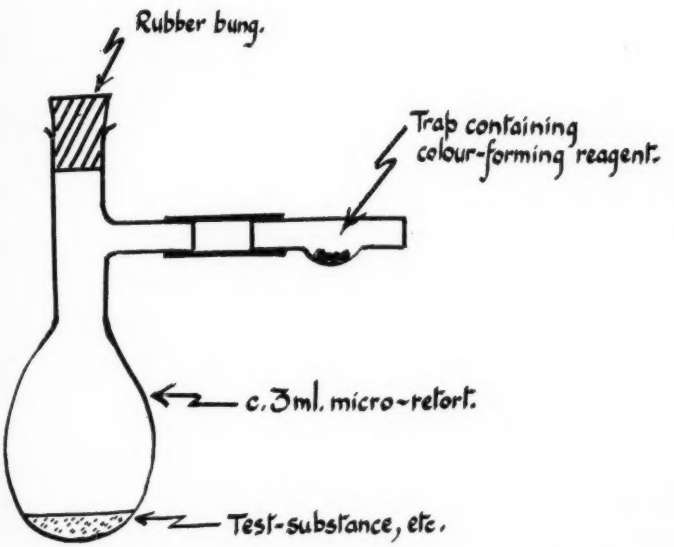

Fig. 1.—Detection Apparatus.

mineral, a little of the powdered sample, together with four to five times its volume of solid aqua-regia, are placed in a 3 ml. micro-retort. The retort is stoppered with a rubber bung and a glass trap containing a few small crystals of stannous chloride is attached to the side arm by means of a short length of rubber tubing (Fig. 1). The retort is then warmed for 3 or 4 min., when the presence of selenium is indicated by a red tint appearing in the trap.

In addition to certain obvious advantages the grinding technique offers another in that certain specific reactions can be employed which would be quite useless were they attempted in aqueous solution. The following test for tin in cassiterite is an example of the type which will only " work " when solids are ground together :—

A little of the powdered mineral is mixed with some zinc powder and a drop of 1 : 4 HCl is added. The mixture is then evaporated to dryness and a small quantity of dimethylglyoxime is ground vigorously with it. The presence of tin is indicated by the development of a rose-red complex which, unlike that due to nickel, is stable in very dilute HCl. Further tests, which are only successful when the grinding technique is used, are described later.

Practical Details of Certain Tests

It must be emphasized that the following is but a selection of the tests described by Isakov and others (see references at the end of the paper). It contains, however, those tests which are particularly good and which, if carried out, will enable the potential of the technique to be determined. For reasons of economy of space a discussion of the chemistry of the various reactions has been omitted.

Finally, it must be stressed again that unless very small quantities of test substances and reagents are used the tests will usually be inconclusive.

Antimony

Test 1.—The potassium hydroxide test for stibnite (Sb_2S_3).

Procedure :—Grind a very small fragment of the mineral with an equally small piece of potassium hydroxide. The presence of stibnite is indicated by the development of a pale-yellow colour which, within a few minutes, changes to orange-red.

Test 2.—The Sudan III test for trivalent antimony.

Procedure :—Add one or two drops of concentrated H_2SO_4 to a little of the finely-ground mineral and then evaporate to dryness. Cool, and grind the residue with an extremely small fragment of Sudan III. The immediate appearance of an intense blue indicates the presence of trivalent antimony.

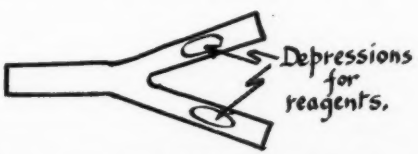

Fig. 2.—Y-Shaped Trap for Simultaneous Detection of Osmium and Ruthenium.

Other notes:—(i) The test will fail if too much reagent is used as the product will be black.

(ii) Under the conditions of the test the reaction is specific.

(iii) If one breathes on the mixture the blue disappears: this shows that the reaction cannot be carried out in aqueous solution.

Arsenic

Test 1.—The detection of arsenic in arsenates.

Procedure:—Grind a small fragment of the mineral with a little $KHSO_4$. Breathe on the mixture, then grind a little silver nitrate with it and add a small drop of water. The presence of the arsenate ion is indicated by the development of a reddish-brown colour.

Test 2.—The detection of arsenic in arsenides and sulpharsenides.

Procedure:—Place a little of the finely-ground mineral in a micro-retort and add to it 4–5 volumes of solid aqua-regia which has not been previously melted. Mix well. Attach a glass trap containing a little ammonium molybdate damped with nitric acid and, after "corking" the retort, warm it for a few minutes. The appearance of a yellow colour in the trap proves the presence of arsenic.

Barium

To detect barium in witherite ($BaCO_3$) *or barytocalcite* [$CaBa(CO_3)_2$].

Procedure.—Fuse a little of the powdered mineral with about four times its volume of solid aqua-regia which has not been previously melted. Grind a small portion of the cooled melt with a few fragments of potassium chromate. The appearance of a yellow colour indicates the presence of barium.

Bismuth

The following tests may be used to detect bismuth in any mineral in which it is a major component.

In order to detect bismuth in minerals with a metallic lustre—for example, bismuthinite (Bi_2S_3)—a little of the test-substance must first be decomposed by warming it with four to five times its volume of ammonium nitrate, then a portion of the product is ground with the appropriate test-reagent. On the other hand, if the element is to be sought for in such minerals as bismite (Bi_2O_3), or bismutite ($Bi_2CO_5.H_2O$?), preliminary decomposition is effected by grinding with $KHSO_4$.

Test 1.—The ammonium chromium thiocyanate test.

Procedure.—Having breathed on a small portion of the bisulphate—or nitrate-decomposed sample—add a fragment of ammonium chromium thiocyanate to it and grind the mixture. Bismuth is indicated by the appearance of an orange-red colour on breathing on the ground material.

Other notes.—Unless a very small amount of reagent is used, the final colour is not orange-red, but yellow.

Preparation of the reagent.—Grind together, in a porcelain crucible, one part (by weight) of either chromic nitrate or chloride and three parts of ammonium thiocyanate. The product, which is green and damp, must be carefully dried in an oven before use. When dehydrated the reagent is of a lilac colour and it must be stored in a tightly-stoppered glass bottle.

Test 2.—The pyrogallol test.

Procedure.—A little of the appropriately decomposed sample is damped by breathing on it and then a little pyrogallol is ground into it. The presence of bismuth is indicated by the appearance of a yellowish-green colour.

Other notes.—The test is specific for bismuth and cannot be executed in aqueous solution.

Boron

To detect boron in evaporite minerals.

Procedure.—Grind a fragment of the mineral with a few grains of quinalizarin and then add a small drop of concentrated H_2SO_4. In the presence of boron the reddish-violet colour of the original mixture instantly changes to blue.

Other notes.—Most of the elements which interfere when the test is carried out in aqueous solution do not do so under the above conditions.

Cerium

The detection of cerium in monazite (*essentially a phosphate of the rare earths*) *and other cerium-rich species such as loparite* [$(Na, Ce, Ca)(Nb, Ti)O_3$], *and rinkite* [$(Ca, Na)_6\ (La, Ce)_2\ Ti(SiO_4)_4\ (F, OH)$].

Procedure.—Place a little of the ground mineral in a crucible and add one or two drops of concentrated H_2SO_4. Warm until the acid has evaporated and then cool. Transfer a little of the residue to a porcelain plate and grind it with a few grains of potassium carbonate, then add one or two drops of hydrogen peroxide. The presence of cerium is indicated by the development of a yellow colour which is intensified on warming.

Chromium

The detection of chromium in chromite ($FeO.Cr_2O_3$).

Procedure.—Fuse a fragment of the mineral with a little sodium peroxide in a right-angled capillary tube. The development of yellow sodium chromate indicates the presence of chromium and this may be confirmed by grinding some of the fusion product with a little silver nitrate when a reddish-brown colour will appear.

Other notes.—The presence of chromium in crocoite ($PbCrO_4$), tarapacaite (K_2CrO_4), and vauquelinite ($Pb_2Cu(CrO_4)PO_4$), may be confirmed simply by grinding directly with silver nitrate.

Cobalt

The ammonium thiocyanate-sodium thiosulphate test, described earlier, is suitable for detecting cobalt in minerals in which it occurs in considerable quantity. However, in most cases the test will fail unless the mineral is first ground with $KHSO_4$.

The final blue colour will fade rapidly if the mixture becomes damp but it may be restored by warming.

Copper

Most copper minerals must be decomposed before they are subjected to the two tests described below. Cuprite, tenorite, chalcocite, chalcopyrite, and other minerals with a metallic lustre, must first be warmed with four to five times their volume of solid aqua-regia, whilst most of the minerals developed in the zone of oxidation—*e.g.*, the carbonates, phosphates, and arsenates—must first be ground with $KHSO_4$.

Test 1.—The ammonia test.

Procedure.—Add one or two drops of 0·880 ammonia to a little of the appropriately decomposed mineral. The development of a blue compound, within 1 or 2 minutes, indicates copper.

Test 2.—The potassium ferrocyanide test.

Grind a little of the decomposed mineral with a few fragments of potassium ferrocyanide. On breathing on the mixture the presence of copper is indicated by the appearance of a brown colour.

Gold

The detection of native gold and of gold in tellurides.

Procedure.—Warm a little of the finely-divided mineral with five or six times its volume of solid aqua-regia until the mixture is yellow. Quickly transfer a little of the product to a porcelain plate and add a few small crystals of stannous chloride to it, followed by a small drop of concentrated HCl. The presence of gold is indicated by the immediate appearance of a brownish-black colour.

Lead

The detection of lead in minerals developed in the zone of oxidation.

Procedure.—Grind a little of the mineral with a small quantity of $KHSO_4$. Add a few fragments of potassium iodide and continue grinding. The presence of lead is indicated by the development of a yellow colour which becomes more intense on the addition of a drop of water.

Other notes.—(i) Certain supergene lead minerals—notably, anglesite ($PbSO_4$)—will react positively when ground directly with potassium iodide.

(ii) The identity of galena may be confirmed by the fact that it is one of the few minerals which, when ground with $KHSO_4$, results in the liberation of H_2S. (Pyrrhotite is another.)

The detection of lead in minerals with a metallic lustre—e.g., galena, jamesonite, etc.

Procedure.—Fuse a little of the powdered mineral with about four times its volume of either solid aqua-regia or ammonium nitrate, then grind a little of the cooled melt with KI as in the above test.

Manganese

As a preliminary to the detection of manganese in most minerals the powdered sample must first be warmed with about five times its volume of solid aqua-regia. Rhodochroisite ($MnCO_3$), and manganocalcite [$(Ca, Mn)CO_3$], however, need only be ground with $KHSO_4$.

Test 1.—The silver nitrate-ammonia test.

Grind a little of the decomposed mineral with a crystal of silver nitrate and then add a drop of 1 : 1 NH_4OH. Manganese is indicated by the mixture becoming black, either immediately, or after slight warming.

Test 2.—The sodium bismuthate test.

Procedure.—Grind the product of decomposition with a little sodium bismuthate, then add a drop of 1 : 1 HNO_3. The presence of manganese is confirmed by the development of the reddish-purple permanganate ion.

Molybdenum

The detection of molybdenum in ferrimolybdate [$Fe_2(MoO_4)_2$], *and other molybdenum-bearing species of the zone of oxidation.*

Procedure.—Grind a little of the substance with a fragment of ammonium thiocyanate, then add a small crystal of stannous chloride and continue grinding. The development of a cerise colour proves molybdenum.

The detection of molybdenum in molybdenite (MoS_2).

Procedure.—Fuse a little of the mineral with about six times its volume of ammonium nitrate and subject a portion of the product to the ammonium thiocyanate-stannous chloride test described above.

Nickel

The general detection of nickel.

Procedure.—Grind a small quantity of the mineral with a little $KHSO_4$, then add a few grains of dimethylglyoxime and continue grinding. The presence of an appreciable amount of nickel is indicated by the development of a rose-red colour.

Other notes.—(i) Garnierite [$Ni_4(Si_4O_{10})(OH)_4 \cdot 4H_2O$], and other nickel silicates react positively when ground directly with dimethylglyoxime.

(ii) As noted elsewhere, ferrous iron does not interfere as it only forms a red complex if NH_4OH is added to the final product.

Osmium and Ruthenium

Osmium and ruthenium often occur together and both elements form volatile oxides. The two elements may be detected simultaneously as follows :—Place a little of the mineral in a micro-retort together with four to five times its volume of solid aqua-regia. Stopper the retort and connect a Y-shaped trap (Fig. 2) to the side-arm. One arm of the trap should contain a little solid sodium hydroxide and the other a little rubeanic acid. After warming the retort for a few minutes a yellow or brown colour will appear in the arm containing NaOH if osmium is present, whilst the development of a blue tint in the rubeanic acid arm will prove the presence of ruthenium.

Palladium

Procedure.—Fuse a little of the mineral with four to five times its volume of solid aqua-regia and grind some of the product with a few fragments of potassium iodide. Palladium is indicated by the mixture turning black and confirmation may be obtained because when palladium is present the mixture will become brownish if after grinding a little more potassium iodide with it a drop of water is added.

Platinum

Procedure.—Fuse a little of the mineral with four to five times its volume of solid aqua-regia. The development of a yellow melt indicates platinum and the presence of the element may be confirmed by grinding a little of the cooled product with a grain of potassium iodide and then adding a drop or so of water. In the presence of platinum a red colour appears.

Other notes.—Quite clearly palladium will interfere, but it must be remembered that this paper contains but a sample of the tests developed by the Russians. In Isakov's work (*op. cit.*) a number of tests are described for each element so that it is possible to identify each one with a high degree of certainty.

Silver

Procedure.—Decompose the mineral by warming it with four to five times its volume of flux which is composed of a mixture of two parts (by weight) of ammonium chloride and one part of ammonium

nitrate. Whilst the mixture is still warm, grind a few fragments of sodium thiosulphate into it. The *immediate* development of a red product, which quickly changes to brown and eventually becomes black, proves the presence of silver.

Other notes.—Under the conditions of the test bismuth causes the development of a pale yellow colour which *slowly* changes to red.

Sulphur

The detection of elemental sulphur.

Procedure.—Grind a little of the mineral with a few grains of thallous sulphide. The presence of elemental sulphur is indicated by the development of reddish-brown bands.

Preparation of the reagent.—Grind together thallous carbonate and sodium sulphide.

Tellurium

The detection of elemental tellurium and the telluride ion.

Procedure.—Place a little of the powdered mineral in a crucible and add one or two drops of H_2SO_4. The appearance of a purplish-red colour on warming proves tellurium.

Thallium

Test 1.—The cobaltinitrite test.

Procedure.—Warm, in a crucible, a little of the powdered specimen with a drop or so of concentrated H_2SO_4 and continue until the charge is dry. Grind a small quantity of the residue with a fragment of sodium cobaltinitrite and then add a small drop of water. The presence of thallium is indicated by the development of a rose-red colour.

Test 2.—The potassium iodide test.

Procedure.—Grind a little of the H_2SO_4 decomposed material with a small crystal of potassium iodide and then add a few fragments of sodium thiosulphate and continue grinding. Thallium is indicated by the presence of a yellow colour.

Other notes.—Sodium thiosulphate is introduced to prevent interference by lead or silver.

Titanium

Procedure.—Fuse a little of the powdered mineral with a little $KHSO_4$ then grind a portion of the cooled melt with a few grains of tannin. In the presence of titanium a reddish-brown or yellow colour develops on the addition of a drop of water.

Tungsten

The detection of tungsten in members of the ferberite–hübnerite ($FeWO_4$–$MnWO_4$) *series.*

Procedure.—Warm a small quantity of the powdered mineral with a little solid KOH until the charge is yellow. Grind the melt with a small crystal of stannous chloride and then add a drop of HCl and warm gently. The presence of tungsten is indicated by the development of a strong blue colour.

The detection of tungsten in minerals other than those of the above series.

Procedure.—Grind a little of the mineral with a few small crystals of stannous chloride and then add a drop of HCl. The presence of tungsten is indicated by the rapid development of a blue colour.

Other notes.—Stannous chloride may be replaced by either powdered aluminium or zinc, but then the mixture must be gently warmed after the addition of the acid.

Vanadium

Procedure.—Warm with a few drops of concentrated H_2SO_4 then evaporate to dryness and cool. Grind a little of the residue with a fragment of ferric sulphate and breathe on the product. The development of a reddish colour indicates vanadium.

Other notes.—Confirmation may be obtained by adding a drop of concentrated HCl to another portion of the H_2SO_4-decomposed mineral. If vanadium is present the mixture reddens.

Zinc

The detection of zinc in minerals developed in the zone of oxidation.

Procedure.—Grind a little of the mineral with an equal volume of ammonium sulphate and breathe on the product. Grind some of the mixture with a small quantity of copper mercuric thiocyanate and add a drop of 1 : 1 H_2SO_4. Zinc is indicated by the appearance of a lilac colour.

The detection of zinc in dark minerals, especially sphalerite (ZnS).

Decompose a little of the mineral by warming it with three to four times its volume of solid aqua-regia and then carry out the above test on a portion of the product.

Preparation of the reagent.—When the reagent (which is green) is needed, prepare it by grinding a small amount of mercuric acetate with an equally small amount of ammonium thiocyanate and then grinding a very small fragment of copper sulphate into the mixture.

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Ore-Dressing Notes

(9) *Gold.*

Old Californian Arrastres

Writing in the State of California's *Mineral Information Service* (Nov., 1959) P. A. Lydon describes the arrastres which were developed from 1850 onward following their introduction from Mexico. Within ten years most of these hundreds of low-capacity mills had been replaced by stamp-batteries. The early types consisted of a low stone curtain wall surrounding a fairly level circular track, paved with stone, a long radial beam attached to a vertical central post being pulled round and round by a mule. A heavy " drag stone " attached to a chain hung from this beam did the crushing work. Ore at *minus* $\frac{3}{4}$ in. was spread over the track and ground to sand size, the charge for an arrastre 10 ft. in diameter being about a quarter of a ton and the grinding time 4 hours. Towards the end quicksilver was added and during the last few minutes water was flushed through. Then a second batch of ore was added and the process was repeated. After some days of this the amalgam and residual sands were removed from the crevices in the grinding track and panned. The track was then repacked with clay between its stones and the work restarted. Among the improvements introduced in their short period of use were a retaining wall of wood planking in place of masonry, the use of two or four drag stones, gating intervals in the circular wall through which finished pulp could be flushed, and replacement of mule power by steam.

Two fairly well-preserved arrastres exist in Sierra County, one 9 ft. and the other 15 ft. in diameter. Both are built chiefly with local granites and metamorphic rock. Drag stones weigh about 150 lb. each and normally would be hung so that the leading edge cleared the track by an inch or so.

(10) *Diamonds.*

Concentration Methods

The concentration of diamond from South African deposits is a fascinating branch of mineral dressing as was brought out in the Presidential Address of R. J. Adamson to the South African Institute of Mining and Metallurgy, reported in the *Journal* for August, 1959. The concentration ratio is of the order of 20,000,000 to one, the stones must be recovered intact and undamaged, and, because of their high value, recovery must be as perfect as possible. In recent years the market for minute diamond particles has grown considerably and this adds to the special problems of diamond recovery. Three main types of ore exist—kimberlite, marine terraces, and alluvial gravels. Kimberlite, the ore of the volcanic pipes and fissures, consists of a blue-grey matrix, chiefly of serpentine, carrying such subsidiary minerals as calcite, diopside, enstatite, ilmenite, phlogopite, pyrite, pyrope, and, rarely, a diamond ; the rock has to be disintegrated to release its diamonds before extraction commences. Marine terraces consist of boulders, pebbles, and grit rounded by sea action together with crustaceous shells, the pebbles being chiefly quartz with some banded ironstone, chalcedony, epidote, felspar, garnet, and jasper. Sand is distributed in overburden and gravel. No crushing or other comminution is required but preliminary screening is used to discard boulders and sand before treatment of the gravel. Alluvial gravels likewise give no problem of disintegration and need only a screening operation to remove silt and oversize boulders.

The production of diamonds of South and South-West Africa in 1958 was 3,600,000 carats, of which 55% were gems and 45% industrial stones. This weight corresponds to some $\frac{4}{5}$ ton and resulted from the mining of over 16,000,000 tons of ore. The ratio of diamond to kimberlite or gravel varies between one in 12,000,000 and one in 60,000,000 parts by weight, with an average of about one in 20,000,000. This tremendous ratio can be realized when it is remembered that for gold a corresponding figure is of the order of one in 150,000. The required mineral-dressing operation is performed in stages, from each of which an enriched fraction emerges. When diamonds were first concentrated in South Africa in 1871 only hand sorting was used, but very soon procedure was modified by the use of a washing cradle and the rotary washing pan, developed in 1874. This met the need far better than had the washing cradles and is still an important instrument in the flow-sheet. For its best use there must be a measure of heavy-media separation produced by the puddled clay coming from the blue ground, which helps to carry the lighter ore constituents over to the tailings weir without preventing the settling of heavy minerals to the bottom of the pan. Mechanically-operated pan plants began at Kimberley in 1888 and were followed by the

use of Harz jigs to reconcentrate the washing pan concentrates ahead of hand sorting. The final stage of hand sorting employed a very large staff and organized research began in 1896 to reduce this section of the work to more manageable proportions. The answer was found when the grease table was originated. From then on hand sorting became a minor step in concentration.

By this stage of development the steps in concentration were : Washing pans, 66 : 1 ratio of concentration ; jigs working on these concentrates, 6 : 1 ratio ; grease tables treating the jig concentrates, 8,000 : 1 ratio, and hand sorting of grease table concentration (6 : 1), giving a final product of diamonds and a total ratio of concentration of 19,200,000 : 1. This stage series of concentration stages at Kimberley can be put another way. Blue ground, 19,200,000 lb. ; discard, 18,912,000 lb. ; concentrate to jigs, 288,000 lb. ; reconcentrate to grease tables, 48,000 lb. ; reconcentrate to sorting office, 6 lb. ; discard, 5 lb. ; final concentrate of diamonds, 1 lb.

At Kimberley, Jagersfontein, and Koffiefontein the washing pan is still the most efficient instrument for original treatment since puddle-forming material is always available. At Kimberley until 1916 the blue ground was first spread out on open fields (floors) each 400 yd. long and 200 yd. wide. Here the lumps weathered down and the danger of fracturing the diamonds was avoided. This entailed storage of some 2,000,000 tons of blue ground per annum over 2 sq. miles. Floors were superseded by coarse crushing followed by primary washing pans in 1916. At the end of World War II an attempt to substitute heavy-media separation at Kimberley was made but it was found that the natural clay medium gave economic advantages over ferro-silicon. Pans are still the first-stage extraction machines and have now had a run of 85 years of use. At Premier mine, where the ore-body is harder, it was found expedient to use crushers and rolls to break up the ore which did not disintegrate regularly. Later jigs were used instead of pans and ultimately Premier went over to heavy-media separation.

Reconcentration of the primary concentrates is done in several ways in the various diamond concentrating plants. At Kimberley heavy-media separation has now replaced the use of Harz jigs. This is followed by a grease vibrator installation. Until 1948 grease tables had a side shaking motion but this was then superseded by the use of high-frequency vibrations on the table deck. The Kimberley series of operations now reads : Washing pan, 32 : 1 ratio ; heavy-media separation, 6 : 1 ratio ; grease recovery, 50,000 : 1 ratio, and hand sorting, 2 : 1 ratio (total 19,200,000 : 1). Grease vibrators have proved so successful at Premier that the heavy-media concentrate, a ratio of 25 : 1, goes straight to reconcentration at 80,000 : 1. This is followed by hand sorting at 7 : 1 to give a 14,000,000 : 1 concentration ratio. Although diamonds from freshly-mined kimberlite respond excellently to grease, those from marine terraces and alluvial deposits have lost this water-repellent property. Research at the Diamond Research Laboratory has found a conditioning treatment which restores the acceptance of diamonds by the grease table. For fine gravels electrostatic separation is preferred. In both cases the surface of the diamonds must be clean and free of any salt films. Heavy-media concentrates are, therefore, scrubbed in small ball-mills for this purpose. Since grease belts and electrostatic separators are somewhat limited in capacity secondary heavy-media has been applied with success to the sink product from the primary circuit. At Consolidated Diamond Mines the steps are now : Field screening and scrubbing, 6 : 1 ratio ; primary heavy-medium separation, 15 : 1 ; secondary heavy-medium separation, 4 : 1 ; attrition milling, $1\frac{1}{2}$: 1 ; grease or electrostatic separation, 100 : 1, and hand sorting, 500 : 1 (a total of 27,000,000 : 1).

As a truck load of *minus* 10-mesh kimberlite has very little value the economics of treatment are strictly watched. Mineral-dressing methods that have been tried without success include flotation, shaking tables, Humphreys spirals, and vibrating strakes. The small differential in specific gravity between gangue and mineral is the main factor in making them unsatisfactory. The sampling problem in connexion with control is very difficult with diamonds. At 90% recovery the weight ratio would be 1 : 600,000,000 for most deposits. This would entail treatment of a 50-ton sample to locate a single carat stone weighing 0·2 grams. and of dimensions of $\frac{1}{8}$ in. Diamond ore consists of about 95% material with a density of some 2·7 and 5% of a mixture of minerals ranging from 2·8 to 4·5 including the diamonds with their specific gravity of 3·5. A variation of the coal washery curve evaluation method has now

been developed by the Diamond Research Laboratory for using the presence of the higher-gravity minerals to give information on the percentage recovery at any particular gravity. Radioactive isotopes give another valuable method of checking the plant performance. Artificial specimens of correct constitution and density can be fed into the plant at various points and tracked by Geiger Muller counters.

(11) *Production.*

The Climax By-product Plant

After steady development through laboratory, pilot, and larger-scale stages which go back to 1946 Climax Molybdenum's by-product plant went to work in the spring of 1958. It treats flotation tailings from the main molybdenite operation to recover tungsten which assays 0·03% in the original ore. It also recovers a little cassiterite and pyrite. The first production plant (7,000 tons daily) started in 1948 and was enlarged to 20,000 tons in 1952. With a subsequent increase in molybdenite milling further expansion was decided on and concentration began in June, 1957.

A simplified flow-sheet is shown in Fig. 1. The mill which houses it is L-shaped. It is flat-roofed and walled with insulated galvanized corrugated steel. Though on two levels most of the work is controlled on one level, with grouped electric consoles near the equipment they regulate. From experience already gained concrete launders were made standard, slopes were graded to main tailings launders, and rubber linings were used where flow rates were high. The 32,000 tons treated daily are handled by a shift of three men with two extra on day shift for routine maintenance. The feed is 12% *plus* 48 mesh and 48% *minus* 200 mesh and is split between two groups of spirals (384 *plus* 320). The pulp arrives on the 5-turn spirals with a velocity below 5 ft. per sec., each appliance receiving 2 dry tons per hour and 5 gal. per min. of water. Concentrates flow to hydrocyclones for dewatering, the underflow being 30% solids and 0·6% WO_3, with 30% pyrite. This pyrite is removed by flotation at pH 5 with ethyl xanthate and is shipped periodically to sulphuric acid manufacturers.

The flotation tail is tabled in two stages and the resulting concentrate assays 40% WO_3. It contains monazite and sands which are feebly magnetic and contain phosphorus. These are floated at 100° F. and a pH of 1·2

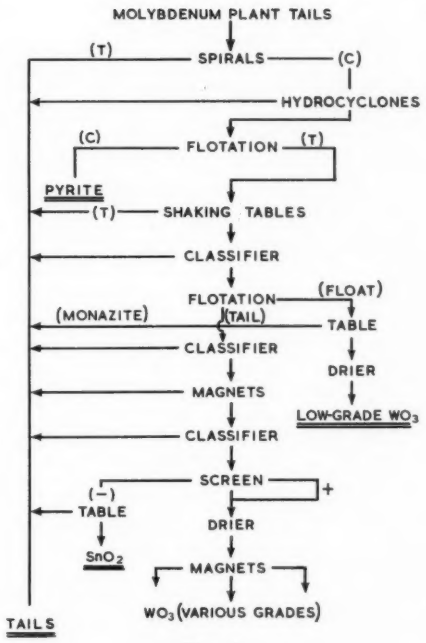


Fig. 1

with an amine (Armac C), starch being used to depress huebnerite. This float is tabled to remove monazite and produce a little low-grade WO_3. The dephosphorized flotation tails are sent to a wet magnetic separator to remove abraded iron, after which they are dried and screened on 50 mesh to produce an undersize which is tabled to recover low-grade cassiterite. The screen oversize receives three stages of dry magnetic separation, which produce three grades of WO_3 concentrate.[1]

Book Review

Optical Mineralogy. By PAUL F. KERR. Third edition. Cloth, octavo, 442 pages, illustrated. Price 66s. London : McGraw-Hill Publishing Co., Ltd.

This book is divided into two parts—"Mineral Optics" and "Mineral Descriptions." Part I is a competent routine treatment of optical mineralogy to full degree level, the illustrations being good although some figures of instruments tend to be of the catalogue type. A particular feature of this

[1] *Min. World* (San Francisco), Nov., 1959.

section is the excellent series of identification tables given in Chapter X. Fundamentally there is nothing particularly new here, but the presentation is first class and the diagrammatic arrangement for the table on the forms of crystals, by catching the eye quickly, is time-saving. The tables cover about 160 minerals.

Part II deals in a very thorough manner with a similar number of minerals, the arrangement being clear and the writing lucid. The treatment of the felspars is particularly good, codifying determination data from many sources within reasonable compass. Illustrations in this part are numerous and excellent.

The author states that " every effort has been made to prepare a text which could be used with a minimum of supervision and a maximum of self-instruction." The reviewer considers he has made his case, but wonders whether the presentation as a whole is not more suited to the large classes in North America than to those in this country. Whether it is fully suited to courses in this country, only a teacher would be justified in saying, and to them the book is recommended for scrutiny. There is naturally a number of well-known books which cover more mineral species than does this one, but if your mineral is not an uncommon opaque one, or a rare transparent one, then you should be able to reach an identification much more rapidly than by using one of the larger standard works.

R. A. MACKAY.

☛ Copies of the books, etc., mentioned under the heading " Book Reviews " can be obtained through the Technical Bookshop of *The Mining Magazine*, 482, Salisbury House, London, E.C.2.

Engineering Log

A recent number of the *Vickers Magazine* records that in July, 1956, British European Airways ordered 20 Vanguards and that on January 20 last the first flight was made, lasting 18 min. First delivery is to be made on March 1 next year and during the 15 months between first flight and entry into service there must be at least 1,500 flight hours of accumulated experience and test. Each of first three Vanguards has eight automatic observers, which consist of large instrument panels which are filmed during the flight and processed afterwards; over 5 tons of instrumentation goes aloft with the aircraft on each test. The programme starts by assessment or production tests. Next come flight resonance trials, handling, autopilot, air worthiness, operation, test of propellers, air conditioning, de-icing, hydraulic and electric systems, cooling, fuel system, radio and flight systems, noise levels, trials under de-icing and tropical conditions, structural integrity, and other tests. All this is additional to the extensive ground testing of the complete aeroplane and its components and systems. The machine must prove itself under every condition it might possibly meet in its working life. None of its characteristics must make unreasonable demands on an average airline pilot under the worst conditions. There is no short cut to safety in the air.

* * *

All rocks are magnetized to some degree by the earth's magnetic field and magnetic prospecting is applicable in some cases to the location of anomalies in this general magnetism. Intensity depends on the magnetic susceptibility of the mineral concerned, which must differ between that of the ore and its host rock. Measured in 10^{-6} c.g.s. units magnetite varies from 100,000 to 1,200,000. Ilmenite is about 300,000, hematite 200–3,000, chromite 245, and zinc blende 0–500. Host rocks such as gabbro, basalt, and granite have from 200–7,000 units, but limestone, quartzite, and sediments are of negligible value. Magnetite, ilmenite, and pyrrhotite are readily located by magnetic prospecting methods. The earliest known instrument used was the Swedish mine compass which goes back to the 17th Century. The Thalen-Tiberg magnetometer was developed in the second half of the 19th Century and was more accurate and sensitive. Although occasionally used, it is slower than the types employed to-day. One of these is a Schmidt variometer or field balance, which measures the vertical component of the earth's magnetic field. This field tends to tip up a magnet and to make it point downward, so that if a weight is added or the balance of the magnet is shifted to restore it to horizontal the strength of the vertical component can be measured. Since the local horizontal intensity affects the instrument reading a variation has been developed in the ABEM and the Askania variometers, which measure the force needed to return the needle to the

horizontal. Other magnetometers measure differences in horizontal intensity. A new type is the Variant nuclear precession magnetometer. This uses the fact that when protons have a strong magnetic field applied to them they are aligned. When the field is removed they spin in the earth's magnetic field and develop a wobble. From this the total intensity can be measured without levelling. The modern magnetometer makes a measurement in some 60 seconds and is used at measured distances along the geological strike to locate anomalies.[1]

* * *

Recent experience with a sulphur-copper alloy, known as No. 120, at the Bridgeport Brass Company, Connecticut, has shown that it is highly competitive with the older generally used leaded and tellurium coppers. Nominal analysis is copper with 0·3% sulphur, as compared to approximately 1·0% lead and 0·5% tellurium in the other two. Sulphur copper has a surprisingly high electrical conductivity. Even in the hard tempers in which it is normally furnished it has a minimum conductivity of 93% and averages 95%–97% of the international annealed copper standard. This compares favourably with the 99% (as annealed) claimed for leaded copper and is considerably better than values of 90% minimum indicated for tellurium copper. This factor naturally points to the value of sulphur copper in many electrical applications. Thermal conductivity is also high and suggests uses for welding torch tips or similar products where rapid dispersal of heat is desired. For machinability sulphur copper is unsurpassed by any high-copper alloy. Its rating of 90 is equalled only by tellurium copper and it shows a definite advantage over leaded copper which carries a rating of only 80. On the same scale regular electrolytic tough pitch copper has a rating of only 20. (These machinability figures are based on 100 for the standard free-cutting brass rod.) Alloy No. 120 has also about the same mechanical properties as tellurium copper but with better ductility and is excellent for both cold and hot working. The most common applications for the new alloy will probably be electrical, because of the high conductivity, while parts may be readily cold or hot forged, headed, or machined for inclusion in electrical or electronic units. Examples are switch parts, transistor bases, and screw machine items. Other applications are for welding torch tips and soldering tips both of which may require forging and machining. Torch tips, in particular, are subjected to a severe drilling operation during fabrication. It is reported there is less wearing away of the metal when using No. 120 alloy than when using tellurium copper for soldering-iron applications. Further experimental work is in progress on sulphur copper in strip or plate form and it looks very promising as a production item.

[1] *New Scientist*, Jan. 28, 1960.

* * *

Figures issued recently by the Petroleum Information Bureau show that United Kingdom oil consumption rose by 17·5% in 1959, as compared with the previous year, to reach a total of 36,500,000 tons (excluding bunkers for ships engaged in the foreign trade). Among the major products fuel oil consumption (including that for public electricity generation) again showed the greatest increase, being almost a third higher than that for the previous year and reaching 13,811,874 tons. Additional quantities of this product were also consumed in the oil refineries. Gas and diesel oil deliveries were up by 4·6%, but usage of this product in gasworks is declining because it is being replaced by light distillate feedstock and petroleum gases. If gas oil for gas making is excluded, the increase in demand for gas and diesel oil amounted to 13·3%. Altogether 7,123,569 tons of motor spirit were consumed during the year—7·5% more than in 1958. The ever-increasing popularity of premium grades amongst motorists is shown by the fact that demand for these was 16% up, while that for standard grades fell. Deliveries of motor spirit to garages and service stations were higher by 10·8%, but consumption of motor spirit by commercial users fell by 3%, owing to the growing preference for diesel-engined vehicles. The demand for " derv " (diesel-engined road vehicle) fuel expanded by 11%. Although 1959 had the highest average temperature recorded for many years, burning oil deliveries rose by 7% to 1,203,118 tons. Demand for aviation fuels was 4·1% higher at 1,628,425 tons (thus reversing the downward trend of the first nine months of the year). Deliveries of propane and butane increased by 40·5% and bitumen consumption reached a record figure of nearly a million tons as a result of increased road-building activity.

News Letters

BRITISH COLUMBIA

April 6.

Land Sale.—The British Columbia Department of Mines and Petroleum Resources has given notice of a sale of Crown petroleum and natural gas rights in the Province to be held at Room 406, Douglas Building, Victoria, on July 14. Anyone requesting that acreage be offered for sale at that time must provide the Chief Commissioner, Petroleum and Natural Gas Act, Room 409, Douglas Building, with a description of the land. Applications will be received to and including May 24, 1960, on the understanding that the applicant will bid on the parcel requested if it is offered for sale. A request for the inclusion of any parcel in the sale does not necessarily assure approval.

Skeena.—Ore reserves of Silver Standard Mines in the Harriet Harbour area, Queen Charlotte Islands, are now estimated at 2,000,000 tons, grading 50% iron. At the projected production rate of 300,000 tons of concentrate annually a five-year continuous operation is therefore assured. An agreement with Sumitomo Shoji Kaisha, whereby the latter agreed to purchase iron concentrate and to participate in financing production cost, is awaiting Japanese approval of the export of the required currency and confirmation by Japanese engineers of the ore reserves. Silver Standard staked several claims in other parts of the Queen Charlotte Islands last month but has not as yet discovered any ore-bodies of economic importance.

Nicola.—Imperial Metals and Power has been incorporated to engage in anticipated industrial development in the Merritt area. The company has acquired title to two major coal properties and to iron and base-metal prospects. The Coldwater mine, long a profitable colliery, contains 50,000,000 tons of available coal of 12,000 B.Th.U. quality; the company also holds a lease on the old Coalmont mine. The Lodestone copper prospect and Iron Cap limonite deposit are both near Merritt and the Heffey Creek copper property, on which an exploratory programme is now in progress, is north of Kamloops.

Greenwood.—At the end of March Sheritt Lee Mines had extended the high-grade silver ore-shoot in the east drive on the 4,200-ft. level to a continuous length of 134 ft. with the face as yet in ore. At the same time diamond drilling is being carried on from the west face of the drive to reach other indicated ore-bodies at depth. The company president, Mr. Karl Wickstrom, states that 200 tons of development ore have been set aside for shipment and that the balance of the drive material will make good mill-feed at a later date. The shipping-grade ore is visibly similar to that contained in a trial shipment last autumn which brought net smelter returns of $185 per ton.

Nelson.—Canadian Exploration, Ltd., produced 9,897 tons of concentrates at Salmo in the quarter ended January 31, recovery being made from 95,803 tons grading 3·01% lead and 4·33% zinc. Cumulative production for the first nine months of the current fiscal year is 24,914 tons of concentrates from 253,640 tons of ore assaying 2·70% lead and 4·22% zinc. Estimated gross operating profit for the nine-month period is $699,931.

New Zealand.—South Seas Mining has commenced development of the Sylvia gold property, three miles north of Thames, on the Coromandel Peninsula. Former underground entries are being rehabilitated and reclaimed and diamond drilling has been started from surface. An elaborate deep-drill test will be made from underground stations as soon as these can be established. The very high-grade deposition of the mine is evident from the available record of production—95,344 oz. of gold bullion from 45,712 tons of ore milled. This remarkable recovery, in the opinion of Dr. A. G. Pentland, the consulting geologist, represents only half the gold content, for the tail loss in the treatment processes of the times is estimated at 50%. A deep diamond-drill intersection has cut a true width of 12·0 ft. of ore grading 1·45 oz. of gold and 6·8 oz. of silver per ton at a vertical depth of 350 ft. below the previous bottom level of development.

Coal.—Shareholders of the Crow's Nest Pass Coal Co. have been asked to approve a resolution granting a four-year option to Columbia Iron Mining, a subsidiary of the United States Steel Corporation, to buy part or all of the coal lands in the Fernie area. The proposal gives Columbia Iron the right to buy for $10,000,000 all of the Crow's Nest company's unworked coalfields, on which the optionee agrees to spend $500,000 in exploration and metallurgical investigation. If sufficient coal is not found during the four-year period in the unworked lands Columbia would then have the right to exercise a second option calling for payment of $17,000,000 for all coal lands *plus* the present Crow's Nest coal operations and facilities.

The Crow's Nest company's numerous other interests in lumbering, petroleum, and natural gas development and electric power projects are not included in the option. The company is currently making delivery of 225,000 tons of coking coal on a Japanese order and is making use of the new bulk-loading terminal at Vancouver for transshipment. The company also supplies from 70,000,000 tons to 100,000,000 tons of coal annually to the Consolidated Mining and Smelting Co. of Canada, Ltd., for the Trail and Kimberley operations.

Canadian Collieries Resources, Ltd., is to cease operation of the T'Sable River colliery near Cumberland, Vancouver Island, within the next few months. The mine has been sold to private interests, including notably three long-time employees who will continue to operate it at approximately 300 tons daily. At peak 3,000 miners were employed in the company's coal mines in the Cumberland area. The T'Sable River mine is quite a modern colliery, commissioned since the end of World War II. Last year it produced at the rate of 1,000 tons daily and so far in 1960 has been turning out approximately 800 tons daily of high energy product. T'Sable River is the last of the big collieries on Vancouver Island and since the shutdown of the Mercoal mine on the Coal Branch south of Edson, Alberta, the last of the numerous collieries to be operated by the present Canadian Collieries company and its predecessors.

Some Annual Reports.—The operating profit of Granby Mining during 1959, as a result of the metal-mining operations of the subsidiary, Phoenix Copper, and the Allenby foundry operation, was $49,924 after all charges including administration and taxes. The Phoenix Copper mill treated 175,945 tons of ore for an average of 679 tons a day

since commencement on April 14, 1959. Average heads were 0·805% copper with 0·034 oz. of gold and 0·193 oz. of silver per ton. At the year-end the mill capacity was increased to 1,000 tons daily and the larger tonnage since handled is expected to increase profit in 1960. Although normal engineering methods are incapable of calculating ore reserves because of the broken nature and inaccessibility of old pillars, caved material, and ore remnants comprising most of the material being mined, the management and engineering staff are confident there exists ample mill-feed for four years' operation at full capacity. Granby advanced a further $75,000 in 1959 to Granisle Copper, Ltd., another subsidiary, for additional drilling of the Babine Lake prospect on which a reserve of 22,000,000 tons is estimated to grade 0·56% copper. If production should ensue the mining would be accomplished by low-cost open-pit methods, to which the deposit lends itself admirably. Granduc Mines, in which Granby holds 1,063,947 shares, conducted a geological study of its mine near Stewart and of the surrounding area. Owing to the short season the work was not completed and accordingly will be resumed in 1960.

The annual report of Bralorne Pioneer Mines for 1959 covers 13 months' operation of the Bralorne mine and 11 months' operation of the Pioneer mine. Bralorne production was 112,727 oz. of gold from 153,119 tons of ore milled and Pioneer produced 30,386 oz. from 70,749 tons. The value of the combined production, including Emergency Gold Mining Assistance, was $5,094,649 and other income was $88,444. The net profit for the period was $486,224. Ore reserves are estimated at 652,000 tons grading 0·77 oz. of gold per ton in the Bralorne mine and 114,000 tons assaying 0·46 oz. per ton in the Pioneer mine. Production was less than capacity owing to interruptions caused by mill experimental work, method changes underground, and extensive development activity. At December 31 the sinking of the Queen shaft had reached a point 90 ft. below the 37-level horizon and stations had been cut for the 36 and 37 levels.

Despite a decline of $118,000 in working capital during 1959 the president, Dr. W. B. Burnett, states that Cariboo Gold Quartz Mining Co. is in a much stronger position than a year ago. A new high-grade mine has been established in the Burnett zone and replacement reserves in the Aurum mine have been increased. Production during 1959 was 17,746 oz. of gold and 2,199 oz. of silver from 46,586 tons of ore averaging 0·3978 oz. of gold per ton. The subsidiary, French Mines, Ltd., continues to find new ore as fast as it is mined in the French mine at Hedley.

The gross value of concentrates produced by Reeves MacDonald Mines during 1959 less smelter charges was $1,970,276 ($1,709,553). Production for the year consisted of 32,320 oz. of silver, 8,816,245 lb. of lead, 28,533,076 lb. of zinc, and 160,734 lb. of cadmium from 421,593 tons of ore milled. Mr. Jens Jensen, the company president, describes development work as follows: "Development work progressed at a satisfactory rate in advance of mining to ensure normal future production. Shaft sinking was completed from the 1,900-ft. level to a depth of 1,045 ft. above sea level and all necessary equipment for hoisting was installed. A new ore-body, designated as No. 4, a faulted section, was discovered to the east of the O'Donnell ore-body and development has indicated it contains ore of similar grade to that mined in previous years in our other ore-bodies."

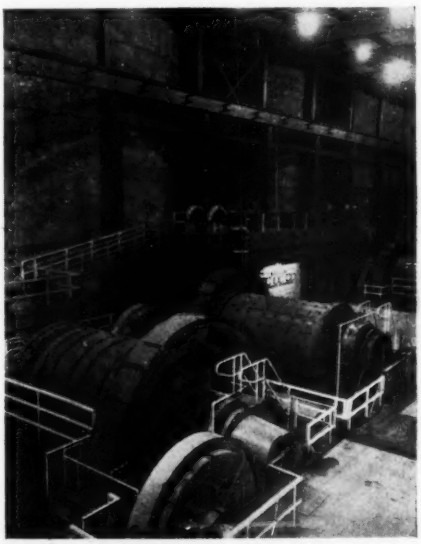
Highland-Bell, Ltd., earned a net profit of $257,878 in 1959. Concentrate sales netted $842,065 and other income amounted to $29,671. The mill treated 18,029 tons of ore averaging 49·03 oz. of silver per ton and produced silver valued at $716,325, lead valued at $58,650, zinc at $45,302, gold at $19,134, and cadmium at $2,653. The company has purchased a 68% interest in Mastodon, Zinc Mines and plans to have the Mastodon mine near Revelstoke, in production by June, 1960. Of particular interest to shareholders was the successful exploration programme of the Mackenzie Syndicate, which resulted in the incorporation of the Canada Tungsten Mining Corporation, Ltd. Work done in 1959 has indicated a reserve of 1,166,351 tons of ore carrying 2·184% WO_3 at a property in the Northwest Territories 150 miles north of Watson Lake, Y.T. Plans for production by 1961 have been given effect.

The Yukon Consolidated Gold Corporation produced gold valued at $1,724,037 from 5,914,587 cu. yd. of gravel mined in seven dredging operations and $70,011 from a combined hydraulic and mechanical operation on the benches of Dominion Creek during 1959. Provisional figures indicate a profit of $95,000.

EASTERN CANADA

April 20.

Ontario Gold Output.—In the Provincial Department of Mines "Gold Bulletin" for February the output of the producing gold mines for the month is given as 222,484 oz. of gold and 35,003 oz. of silver, valued at $7,446,848, from 755,569 tons of ore milled.



Mills and Ore Silos, Levack.

Aeromagnetic Survey Maps.—The Ontario Department of Mines announces the release of ten aeromagnetic maps, Nos. 890 to 899 inclusive, scale 1 in. to 1 mile, covering a belt in the Kenora district. These were prepared for the Department and the Geological Survey of Canada.

Sudbury Area.—A new highly-automated milling plant has been opened by the International Nickel Co. of Canada. This modern mill, located at the Levack mine near Copper Cliff and built at a cost of $12,000,000, makes extensive use of instrumentation to permit centralized and in some cases automatic control of the crushing, grinding, flotation, and dewatering processes involved in the production of concentrates from ore. All operations are controlled from centrally-located instrument panesl. Many recently-developed techniques—such as, the use of radioactive isotopes for making density measurements—have been incorporated into the new plant. The plant is one of the improvements the company is carrying out at its properties in the Sudbury area which, with the new nickel mining project being developed at Thompson, Manitoba, will raise its nickel production capacity to 385,000,000 lb. per year by 1961.

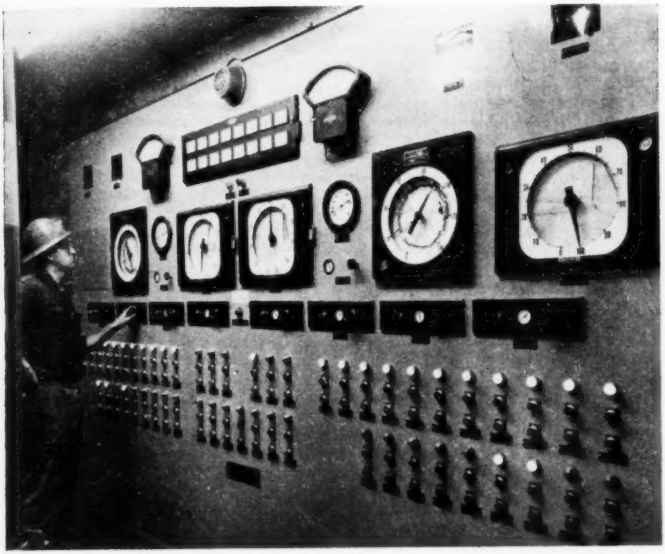
The Levack mill has a capacity of 6,000 tons of ore per day. Crushed ore from No. 2 Shaft is conveyed directly into a concrete silo-type bin with a live capacity of 3,000 tons. Two parallel conveyors feed the coarse ore to two 7-ft. cone-crushers which reduce it to *minus* ¾ in. The crushed ore is then conveyed to three large circular concrete bins with a total live capacity of 16,000 tons, a special screening process removing wood chips *en route*. Automation is used to assist in this crushing operation. The crushers, crusher oil pumps, screens, variable-speed ore feeders, and conveyors are all operated and controlled from a central instrument panel where lights indicate what equipment is in service. The occurrence of trouble in operation equipment sounds an alarm on the control panel and gives a visual indication of the trouble. An indicating and recording weightometer on the panel shows the tonnage of ore being crushed.

The two grinding units each consist of a 15-ft. rod-mill, a 14-ft. ball-mill, and two cone classifiers. A central instrument panel controls the entire grinding operation. The flotation plant follows and this is also automatically controlled by instruments located on a central panel. Concentrates are dewatered in thickeners followed by vacuum filters. The operation of the thickeners and filters is again automatically controlled and thickener underflow pumps and filtrate pumps are remotely operated from the panel. More than 30 railway cars of nickel and copper concentrates are shipped each day to the smelters at Copper Cliff and Coniston, while flotation tailings are pumped 1,500 ft. to the sand plant where approximately 85% of the tailings are recovered as sand fill for use in the mine. This fill material is sent by pipeline directly into the mine.

Iron.—The report of the Anaconda Company for 1959 states that a 100-ton-per-day pilot plant is under construction at the Nakina iron-ore mine site in western Ontario for testing and concentrating representative samples taken from excavation cuts in the Briarcliff and Two Mile Lake ore-bodies. The results of this work will form the basis for the flow-sheets and the construction of a commercial concentrator at some future date. A sizeable programme of road building and construction of an airstrip were also completed.

Quebec.—The report of Aluminium, Ltd., and its consolidated subsidiaries for 1959 gives the sales and operating revenues for the year as $448,691,506, compared with $422,884,184 the previous year. Cost of sales and operating expenses were $292,380,796 compared with $276,724,241. Total dividend disbursements were the equivalent of $15,994,535 in Canadian funds as compared with $22,038,072 in 1958. According to preliminary estimates, the

General View of the Levack Site.



Control Panel, Levack Mill.

report says, the consumption of aluminium in the free world in both primary and secondary forms reached a level of about 4,200,000 tons in 1959—an increase of about 20% over the previous record level in 1956. The growth was well distributed in all geographic areas but was particularly noticeable in Western Europe, the United Kingdom, and Asia. Consumption in Canada and the United States also showed impressive gains. The more important categories of increased use of aluminium were in the fields of transportation, construction, and packaging in a variety of forms. The company's consolidated sales of aluminium in all forms were 643,328 tons, against 581,195 tons in 1958. The progressive increase in sales during the year is vividly emphasized by a record 200,000 tons of sales during the fourth quarter.

AUSTRALIA

April 18.

Gold Production.—Australian gold production in 1959 was the third highest post-war, the total output being 1,089,574 oz. of fine gold—28,168 oz. less than the post-war peak in 1954. Western Australia produced 861,122 oz. or 79% of the total, but the production by this State was less than in 1958 by 13,702 oz. Commonwealth subsidy payable to the gold-mining industry totalled £A788,195, compared with the previous year's payment of £A753,528. Of these amounts Western Australian producers received £A652,266 in 1959 and £A623,394 in 1958.

The main gold producers in Queensland are Mount Morgan and Golden Plateau. In 1959 production was 91,787 oz., valued at £A1,434,171. Production in 1958 was substantially less, at 71,511 oz., valued at £A1,117,539.

Mary Kathleen.—In 1959 Mary Kathleen Uranium made a profit of £A1,967,886 after transfer to reserves. Total ore and waste mined was 1,494,464 short tons, of which 468,041 tons was open-cut ore, the ratio of ore to total waste being 1 : 2·19. The ore milled was 479,990 tons from which 1,452,136 lb. of uranium oxide was recovered, the overall recovery being 90·48%. The estimated ore reserves at the close of the period were : Stockpiled ore, 192,800 tons ; ore in place, 4,164,500 tons ; total ore reserves, 4,357,300 tons, with an average grade of 3·44 lb. uranium oxide per ton. Possible ore, delineated by diamond drilling, was 1,095,500 tons, containing 3·59 lb. uranium oxide per ton. Exploration and development have indicated a much longer life for the deposit than had been supposed and reserves were sufficient to enter into another major contract, if a market could be found. The increase in indicated ore reserves is partly due to extensions of the ore-body and partly to establishment of a better grade than has been originally estimated. Extensions of the ore-body in depth to the north give ground for increase in ore reserves in that direction. An innovation in practice is the installation of an electronic ore sorter to discriminate between radioactive material and waste in the ore, resulting in lower operating costs through eliminating the passage of much waste material through the mill. Change in slope of the open-cut has resulted in the removal of a minimum quantity of ore and additional overburden outside the ore boundaries. Variability in the wet season in North Queensland has a direct bearing on water supply. The present dam has a capacity of 2,900,000,000 gal. of water, but in order to make ample provision for mining and domestic needs a new dam is to be built. Evaporation is a serious factor and to minimize this cetyl alcohol, in powder form, is spread over the surface of the water.

Mount Isa.—Mount Isa Mines is looking ahead for sufficient labour to carry through its expansion programme and to meet a shortage of miners. A school for training miners is to be established. In order to

assist the position the company has applied to the Industrial Court for the employment of one man on drilling machines in rises instead of two, as at present. With airleg machines two men per machine are considered unnecessary and the second man could be employed to much greater advantage elsewhere.

Oil Exploration.—The latest moves in the search for oil have been made by Broken Hill Proprietary, which intends to examine the possibilities of Bass Strait. Application has been made to the Victorian Government for a permit to search off the 90 Mile Beach in the Gippsland area, extending up to 50 miles off-shore. Application has also been made to the Tasmanian Government for a permit covering 33,000 sq. miles seaward from the coastline and including Flinders Island, King Island, and all islands off the northern coastline. No part of the Tasmanian mainland is included in the application. If the application is granted a detailed aerial survey, extending over a period of four years, would be made to ascertain if an oil basin is likely to exist in the rocks below the ocean floor.

In the early years of oil search in Australia, when oil was found in the coastal Tertiary rocks of Victoria, it was thought by some that the oil which was located in a low shallow monocline in the narrow belt of Tertiary formations following the southern coast of the State had migrated from a source in Bass Strait. Another view was that the heavy faulting of the rocks of the Strait made the retention of oil unlikely. For many years bituminous material has been found along the Victorian coast, suggestive of underwater seepage in some part of the Strait through fractures connecting with an oil storage.

One of the first areas giving positive evidence of petroliferous conditions in Australia was Roma, in central Queensland, where gas in some quantity was obtained in drilling. After years of irregular search in the surrounding country attention is again being given to Roma and drilling has been resumed. Petroliferous gas has been met at an area known as Timbury Hills, at a depth of 3,700 ft., flowing at the rate of 1,250,000 cu. ft. per day. The well is to be continued to 4,200 ft. and if gas is present in sufficient quantity will be sealed off.

In South Australia an intensive search in the Great Artesian Basin is to be made along what is known as the Birdsville track, extending from Marree to Boulia, eastward. The work is expected to take six months and to cost £80,000. The search is being made by the South Australian Government and the exploratory party, with its equipment, has set out with a 22-vehicle convey.

In the State of Queensland, south of Boulia, drilling is in progress at Betoota, where a depth of 9,000 ft. has been reached. These localities are toward the western margin of the Great Artesian Basin, in which the Roma country is also situated.

An important step has been taken by the Commonwealth Government in inviting the Petroleum Institute of France to Australia to make a review of petroleum possibilities. Members of the team have arrived and it is expected that several months will be spent on the work. The review of possibilities will be made in two stages. The first will consist of a general survey of Australian sedimentary basins and the second will be a more detailed survey of selected areas. Such a review has been an objective of the Commonwealth Bureau of Mineral Resources, which will co-operate with the French party.

Bell Bay.—There is still some uncertainty as to the ultimate future of the Bell Bay aluminium works, owned jointly by the Commonwealth Government and the Government of Tasmania. Developments have indicated that the throughput of the works can be increased to advantage, but the Commonwealth Government is unwilling to put further capital into the industry. Reports indicate the possibility of the Commonwealth's interest being purchased by the partners in the development of the Weipa bauxite field, on Cape York Peninsula. It is reported that the Bell Bay works will be treating Weipa bauxite by the end of the year. The Premier of Tasmania has predicted that the capacity of the works will reach 50,000 tons of metal per year in the near future. At present bauxite is obtained from Malaya and Indonesia, but it is anticipated that this importation will ultimately be replaced by Queensland bauxite.

Representatives of Japanese smelting interests are interested in the possibility of obtaining supplies of bauxite and it is intended to send a survey group to study the prospects of obtaining supplies. Areas for investigation are the Cape York Peninsula and Western Australia.

Copper.—The Japanese are also interested in obtaining supplies of copper concentrates or even an active interest in Australian copper mines. Contracts for purchase of copper concentrates have been made with Mount Isa Mines, Ltd., and Peko Mines, N.L., and negotiations have been entered into with Mount Morgan. An examination of the Ravensthorpe copper mines was made, but negotiations with a view to a financial interest in the company's operations were finally abandoned. A recent report is to the effect that a group of Japanese companies is considering financing the erection of mining plants on north Queensland copperfields. The Japanese were invited by the Ore Producers Association, a body of small copper producers. Inquiries have also been made into the possibility of re-opening the Whim Creek copper mine, in Western Australia. In earlier years Whim Creek was the largest copper mine in the State but has been idle for a long period except for leaching operations.

FAR EAST

April 13.

Tin Industry.—The import tax on fuel oils imposed in the State Budget still gives rise to concern. At the recent meeting of Petaling Tin, Ltd., in Ipoh, for example, Mr. D. C. Thomson, who presided, suggested that the tax bore heavily on the industry and could well result in the elimination of some producers. Such a trend he said, could not but influence future development and planning, as a stage must be reached where crippling costs would cause abandonment of lower-grade deposits and create less inclination to venture capital in mining with its extremely speculative features. It was hoped that the encouragement given to pioneer industries would not be denied the established ones upon which Malaya was so dependent.

In spite of the recently-imposed tax mining circles in Perak are confident, however, that the country will be able to fulfil her tin production quota for the current control period. Mr. P. A. Delme-Radcliffe, president of the F.M.S. Chamber

of Mines, speaking in his personal capacity, said recently: "Malaya can certainly fulfil her permissible export amount during this quota period. Considerable stocks were accumulated while keeping labour employed that might otherwise have been retrenched throughout the worst days of restriction . . . The tin ore so accumulated is now again serving the country in another way". It provided a protection to Malaya's position as the world's leading tin producer and to the industry by maintaining a permissible export amount, while those mines which closed down were preparing to start up again. Mr. Woo Ka Lim, secretary of the Perak Chinese Mining Association, said there might be a few cases where small miners would not be able to produce their quota, but Malaya as a whole undoubtedly could do so.

Directors of Lingui Tin, which owns tin-bearing areas in South Johore, have announced that, after nine years, mining operations have been resumed. The war against the Communist terrorists in the jungles of Malaya had halted the mining operations in 1951, but now that the emergency was over the Government is allowing mining to be resumed.

Iron Ore.—Perak has become Malaya's second largest producer of iron ore, with a total output last year of 615,238 tons, according to Mr. A. W. Burne, Senior Inspector of Mines, North Zone. This total puts Perak second to Trengganu and ahead of Johore, Kelantan, and Kedah, which are Malaya's other iron-ore producing states. Trengganu easily remained the top producer last year, with a total of 2,116,200 tons. Malaya's total production in 1959 was about 3,750,000 tons.

Singapore.—A steel rolling mill, to be financed jointly by Japanese and Singapore business interests, is to be set up in Singapore. It will use local scrap, principally that obtained from ship-breaking operations, in which it will also engage. It is expected to provide employment for some 400 workers. This mill will be separate from the iron and steel plant planned by the Government, but is expected to be one of the users of billets to be produced at the steel plant.

Sir Alexander MacFarquhar, regional representative of the United Nations Technical Assistance Board, has announced that he will recommend that two U.N. survey teams should be sent out to speed the Singapore Government's industrialization programme. The first would submit a report on the feasibility of the Government's plan to set up the iron and steel plant (the cost of which has been estimated at Malayan $600,000,000), while the other would survey the market, resources, and prices. Singapore has no iron ore, limestone, or coal, said Sir Alexander, and this would have to be borne in mind when the plant project was examined. His board would send men who had the confidence of agencies such as the World Bank.

A (Malayan) $65,000,000 oil refinery with a initial capacity of 20,000 barrels a day is expected to go into operation by the end of next year. Two Japanese firms, Toyo Menka Kaisha, Ltd., and the Maruzen Oil Co. of Japan, have signed an agreement with the Singapore Government on the setting up of the refinery. These firms are to form a subsidiary company—tentatively named Maruzen Toyo Oil (Singapore) Ltd.—to run the refinery. Mr. R. Nishimura, Singapore manager of Toyo Menka Kaisha, said construction of the refinery would be in three stages. The first stage would cost $20,000,000.

SOUTHERN AFRICA

April 28.

Economic Advisory Council.—The Union Government has now appointed the members of its recently established Economic Advisory Council under the chairmanship of Dr. D. H. Steyn, at present Secretary of Finance. The membership will be representative of mining, industry, commerce, farming, labour, and the Central Bank and will include nominees of the Prime Minister for their experience and knowledge of economic and financial matters and of relevant Government departments. Meeting will be arranged as required but at least once a year. The constitution of the Council is flexible enough for amendment and modification as practice may determine.

Uranium.—As already reported the recent discussions between the Combined Development Agency, the uranium oxide purchasing agency of the United States and the United Kingdom, resulted in no changes of current contracts, but further consideration is being given to the position and further discussions may be held later in the course of routine relations. Meanwhile the South African authorities, in conjunction with the Chamber of Mines and the uranium producers, are advancing their combined research and development programme, which will involve expenditure of £4,000,000 over 5 years to the 1964–65 period and which has the object of placing the country's producers in the best possible position to compete in the world's markets.

The South African Atomic Energy Board is financing the erection at the Government Metallurgical Laboratories in Johannesburg of a pilot plant. This is being sponsored jointly by the Board and the Transvaal and Orange Free State Chamber of Mines. The plant will produce or be capable of producing about 100 tons of uranium metal a year and is expected to be commissioned by about the year-end.

Hartebeestfontein Gold Mining has completed the first stage of converting the existing leach section of the uranium plant to the high-temperature ferric leach process.

Gold.—Over the next 30 years gold production in the Union will have an estimated value of about £7,000,000,000, equivalent to an average annual value not much below that of 1959, when the value was about £250,100,000, according to a recent statement of the Minister of Mines. The Minister is at present studying a report on the establishment of a pension scheme for mineworkers and negotiations are proceeding on the question of increasing wages in the industry. Whether this is being considered along with the question of the current tax formula has not been disclosed, although representations on the matter have frequently been made.

Training.—Most of the mining groups have by now centralized and are to intensify training of personnel. The General Mining and Finance Group is establishing a group training school for learner-officials on the property of West Rand Consolidated Mines, where buildings are being erected. The Anglo American Group has also established the training of learner-officials, in this case in their first year, at centralized schools set up on a zonal basis. For instance, the school for the Group's East Rand mines has been established at Daggafontein. The zonal school would appear to have the advantage of training for zonal conditions. This may not be as

flexible as general schools, but doubtless the training would be broad enough to facilitate transfer of personnel as the need arises.

Trade.—Imports into the Union over the first two months of 1960 were valued at £88,383,000, against £78,621,000 in the corresponding 1959 period. Exports in the first two months of 1960 advanced to £69,723,000 from £64,223,000 in the corresponding 1959 period. Including private sales through authorized channels gold sales in the first two months of 1960 were £37,752,000, against £37,321,000 last year, which values are not included in the export returns.

In its review of economic conditions the South African Reserve Bank projects these in 1959 against developments in 1957 and 1958. The adverse conditions in the second half of 1957 resulted from price declines in raw-material exports and the severe credit squeeze and rise in interest rates in the United Kingdom. To counter these developments the Union in 1958 applied bank credit restrictions, imposed stronger foreign exchange control measures on Union residents, and raised certain interest rates. As 1958 progressed the trade deficit improved, a substantial net inflow of capital ensuing, which were accompanied by a reversal of the United Kingdom interest rates and credit squeeze. However, recessionary tendencies arose with the continued decline in raw-material export values, despite the marked improvement in the balance of payments. In 1959 the internal monetary policies were eased to counter the recessionary economic tendencies becoming evident. Over that year mining production excluding quarry products rose to a record level, the advance mainly reflecting higher gold output. The other economic sectors were patchy, agriculture being sluggishly maintained, manufacturing appeared to ease somewhat, while building and construction improved but irregularly. External trade reflected sharply reduced imports and substantially better exports. Generally outside gold mining the tendency in 1959 was sluggish, aggravated by what could be described as psychological factors which tended to overshadow improvements in the internal trade. These factors may have been associated with the net outflow of capital in all forms of about £33,000,000. Owing to the favourable balance of payments in 1959 there was strong pressure internally of funds seeking investment outlets, mainly from institutional sources. Interest rates therefore showed a downward tendency over the year and on balance it was found that gross domestic capital formation in 1959 showed a considerable decline. The year ended with available evidence pointing towards a gradual but distinct economic recovery, with the Minister of Finance in his Budget proposals for the 1960–61 year announcing a number of tax reductions and other priming measures to stimulate further internal economic development.

Iron.—The production of pig-iron from an iron-ore deposit on the property of Leeuwbosch Lead Mine, Ltd., about 10 miles north of Thabazimbi in the Rustenburg area of the Western Transvaal, is the subject of negotiations between the judicial managers of the company and Japanese interests. The property is at present on tribute to Fritzmorr Exploration (Pty.), Ltd., which would participate in the joint venture with the Japanese interests in the event of the negotiations reaching a satisfactory conclusion.

Transvaal.—According to the most recent information from South African Land and Exploration Co., Ltd., the reef formations in the deep sections of the old lease area and in the northern section of the new Withok lease area conform to a syncline. These formations will be worked in the immediate and near future. With the southern limb, in the northern Withok section, upcast by the tear-fault relatively sharply, the tonnage per claim appears considerably higher than originally expected. Further to the south and especially to the south-east the reef formations are apparently again downcast by another fault system. Reef development disclosures in the northern Withok section so far explored have been distinctly promising and reasonably encourage the expectation that the Withok section will prove almost another mine in itself or at least provide tonnages for many years of operations. In 1959 almost all the Withok footage sampled was north of the tear-fault, where values averaged 222 in.-dwt. against 238 in.-dwt. over a small footage south of the fault. Here operations remained limited by reason of restricted ventilation which will be increased to levels permitting extension further southwards only when the new shaft system has been completed. The vertical component, 18 ft. lined diameter, is being sunk to 4,270 ft. and will be used solely for ventilation purposes, while the 24-ft. lined diameter sub-vertical component will be sunk to 7,450 ft. and used for hoisting. An indirect benefit from the higher-grade Withok ore may be the mining of greater tonnages of marginal ore in the old lease area, with an extension of that area's economic life. In 1959 a greater development effort was relatively devoted to proving possible extensions of payable shoots with the effect of reducing the area's payability. Further information of the geological formation of the ore-body south of the tear-fault in the Withok section is that the upcast south of that fault appears to persist for a considerable distance to the south, especially in the eastern section, apart perhaps from localized faulting. Further disclosures from development more to the west may confirm this persistence more to the west.

Durban Roodepoort Deep continued its development operations in 1959 to open up the deeper levels of the Main Reef horizon. A feature of these operations in the western half or section of the mine has been the employment of the longwall method of mining, following the cutting of four foot-wall winzes. A considerable portion of the development effort was again off-reef, which accounted for the full effort not being immediately reflected in the Main Reef ore-reserve tonnage. Development on the shallower Kimberley Reef reflected further expansion and improved values and payability but not quite to the extent of offsetting the conditions on the Main Reef. Work on extending the capacity of one gold plant to the range of about 200,000 tons to 240,000 tons a month preparatory to the closing down of the older plant is in progress.

East Daggafontein Mines is advancing exploratory development eastwards and over increasing footages in the Rietfontein section ; it has disclosed satisfactory payability and values on both the Main Reef Leader and Kimberley Reef horizons, with Kimberley Reef payability in one section relatively low. More to the west operations are now mainly directed to the cutting of stope blocks, primary development having been largely com-

pleted. Generally Kimberley Reef operations are responsible for the improved ore-reserve tonnages.

Following abnormal activity earlier in the year platinum demand has quietened somewhat. However, Rustenburg Platinum Mines, Ltd., has maintained output in order to build up stocks which had been reduced to relatively low levels. Operations will, however, be adjusted to the needs evident from time to time. Sales in the year to the end of August, 1960, are expected to exceed those in 1958–59.

West Driefontein has resumed sinking the No. 4 Shaft in the north-eastern section, where values are expected to be lower than those to the west. However, bore-hole results to the south have shown that values can be expected to improve with depth, as may apply throughout the mine. At the end of March a depth of 1,836 ft. had been reached.

Dominion Reefs has commissioned its new flotation plant for the recovery of gold concentrates and operations are proceeding normally, with initial results reflecting the usual gold lock-up associated with running-in a new plant.

Stilfontein Gold Mining has completed extensions to the plant, which now has an operating capacity range of 180,000 tons to 225,000 tons a month. Operations preliminary to the sinking of the Scott shaft, 4,000 ft. south-west of the Margaret, are proceeding. The new shaft will serve the south-western section of the mine down to the southern boundary.

Primary development on the Main Reef horizon at East Geduld has been practically completed and development henceforth will be largely confined to stope formation. Primary development continues on the Kimberley Reef horizon.

Orange Free State.—At St. Helena operations in the higher-grade north-eastern section will benefit and probably be accelerated with the connexion effected between the No. 2 shaft workings and No. 7. This has resulted in an increased ventilation flow. The No. 7 shaft in the first quarter reached a depth of 4,013 ft., where a holing was effected with No. 18 Level cross-cut from the No. 2 shaft workings in the north. This cross-cut is being driven farther east towards the common boundary with President Brand.

Doubtless due to increased footage in the higher-grade No. 2 shaft area development values in the Harmony lease area improved in the first quarter to the highest level for some considerable time.

Free State Saaiplaas has initiated development off-reef from its recently completed No. 2 shaft and in the first quarter continued reef development in the No. 1 shaft area, where values declined sharply to 283 in.-dwt. To the end of March aggregate development results were 4,380 ft. sampled, 1,815 ft. or 41·4% payable, averaging 452 in.-dwt. The indicated bore-hole grade range for the lease area was 320 to 500 in.-dwt. and payability 50% to about 70%.

Freddies Consolidated hopes that before the year-end an exploratory haulage being advanced westwards will be sufficiently advanced to permit drilling up into horizons in the Elsburg Series and to test any values therein. Disclosures on Elsburg Reefs to the west in the Loraine mine have undoubtedly promoted this venture on the part of the Freddies mine, which is beginning to face the prospect of closure and disposal of assets or being placed on a care and maintenance basis. If current working losses are not eliminated by about the mid-year the current development programme will probably be curtailed. It will however apparently be continued, even at a lower tempo, until sufficient disclosures have been obtained from the Elsburg horizons.

Trade Notes

Brief descriptions of developments of interest to the mining engineer

Mineral Processing Exhibition

Some notes follow on items noticed at the exhibition which were not covered in the advance guide published in the March issue.

William Boulton, Ltd., drew particular attention to the Podmore-Boulton vibro energy mill, for the ultra fine grinding of various minerals wet or dry. The company's range of products include ball and pebble mills, agitators and mixers, classifiers, thickeners and screens. Included in the last named is their gyrating screen which incorporates a number of movements that can be used singly or in combination, enabling it to handle a wide range of materials.

Eimco (Great Britain), Ltd., called attention to their range of rotary vacuum and pressure filters, thickeners, and clarifiers which they supply in association with the Eimco Corporation of Salt Lake City, Utah. Interest particularly centred on equipment developed for the uranium industry which includes some of the largest precoat vacuum filters ever made.

General Electric Co., Ltd., in addition to the features of their display to which attention was drawn in the March issue were also

signalising the 100 years of Fraser and Chalmers Engineering Works service to the mining industry. To mark the occasion a booklet has been produced which traces the development of the works at Erith up to the present day. This also illustrates the various machines for the supply of which the company has become well known from the early steam-driven stamp mill—crushers, screens and feeders, crushing rolls, washing plants, heavy-media separation, Humphreys spirals, magnetic separators, ball and rod mills, sand pumps, cyanide plants, blowers and compressors, the Chance process of coal cleaning, materials handling plant, winding engines, and power plant being some of the items included in the survey.

Hadfields, Ltd., had a display of photographs illustrative of their range of crushing machinery and equipment together with a model of a 72 in. by 48 in. double-toggle jaw-breaker. Attention was also drawn to the products of their associated company Ernest Newell and Co., Ltd., which include conveyors and elevators, apron and belt-type feeders, and ball, tube, and rod mills.

Imperial Chemical Industries, Ltd., from their Dyestuffs and General Chemical Divisions arranged a display to show the applications of their products in flotation, smelting, refining, and various hydrometallurgical extraction processes. Among items included were samples of collectors, depressants, activators, flocculants, frothers, and solvents.

International Combustion (Export), Ltd., had on their stand models of Ty-Rock and Hum-mer screens, a laboratory size Rovae filter, and an example of the smallest in the range of Vacseal pumps. Attention was also drawn to Rovac disc and cell filters for full-scale operation and to the other grinding, screening, filtering, pumping, and classifying equipment available.

Rapid Magnetic, Ltd., made a feature of their "Unigap" high-intensity magnetic induced roll separator, as illustrated here, which is suitable for ilmenite, monazite, and tantalite concentration. The unit has a 5-in. diameter roll with two 5-in. feed widths and several such units can be fitted together to provide a machine suitable for cases where selective separation of different minerals is required.

George Scott and Son (London), Ltd. were showing the Scott Wemco torque-flow pump, the salient feature of which is a recessed impeller located completely out of the flow pattern which imparts a swirling action to the material in the suction line. Thus the suction and discharge become one continuous passage and choking becomes virtually impossible. The principle of the pump was illustrated in the note which appeared in the MAGAZINE for August last (p. 59), when it was exhibited by Wests Manchester, Ltd. at the Mining Machinery Exhibition.

Unigap Separator.

Blast Recorder

An instrument has been designed for measuring and recording the acceleration of a point of interest in the vicinity of a dynamite or other explosion blast. The acceleration of the point is used as an indication of damage which might occur as a consequence of blasting activities. Known as the Blastcorder Model 5050 it is made by the **Geotechnical Corporation,** of Garland, Texas.

The Blastcorder senses the peak acceleration of structural vibrations and provides the operator with an indicating meter to help him control blasting vibrations within safe limits and to demonstrate easily the safety of his work by showing how a normal disturbance, such as a slamming door, will often

Recording a Blast.

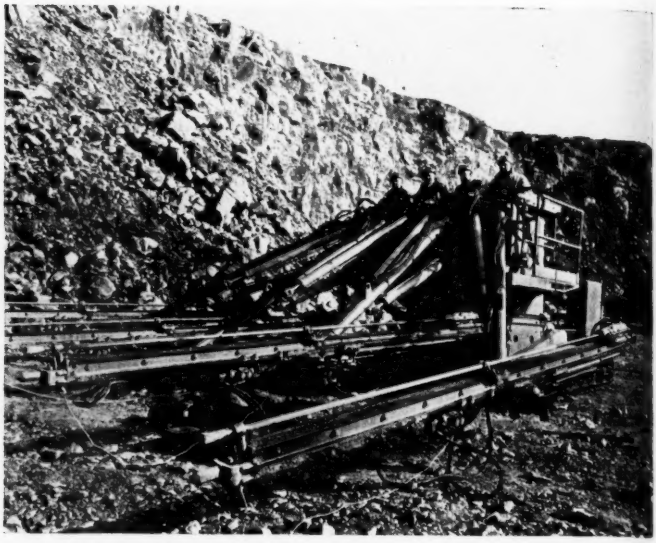
produce a higher reading than did the blast itself. It will also give an immediate record to help the blaster to avoid costly delays and lawsuits by satisfying vibration complaints on the spot.

The instrument, which with accessories is mounted in a Fibreglass case, is easily carried, weighing about 20 lb. and measuring 6 in. by 12 in. by 19 in. The vibration pick-ups, the ground stakes, and the records are carried in the lid of the case. Meter, controls, and a slot for inserting the record are mounted on the instrument panel. The meter enables pick-ups to be calibrated in the field, the batteries to be checked quickly after storage, and acceleration to be monitored or demonstrated visually. It is powered by batteries of standard makes and additional plug-in amplifiers and pick-ups are available for converting the instrument from one to three pick-ups. The records are of durable transparent film 4 in. by 6 in. in size. Spaces are provided on the record for entering shot data —such as, date, time, location, charges, delays, distance, signatures of operator and witnesses, and other items. The fixed scale on the record is from 0 to 1.1G's of acceleration. Pressing the " Expose " button photographically prints a mark opposite the scale on the record, thus recording the amount of acceleration detected. Depressing the " Develop " button after exposure activates heating coils, making the record permanent. The record can be reproduced by most conventional office copying machines. If additional pick-ups are used to detect vibrations in more than one direction the instrument will record the acceleration from the pick-up receiving the maximum vibrations. Instructions for its use are printed in the lid of the case.

Mobile Tower Drill Rig

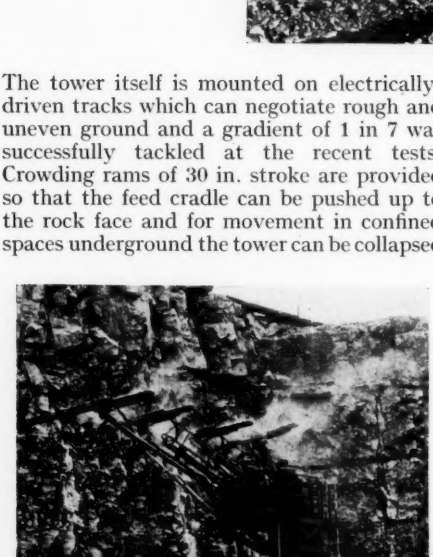
The issues of the MAGAZINE for August and December last contained brief notes relating to a Russian contract obtained by **F. Taylor and Sons (Manchester), Ltd.,** and **Climax Rock Drill and Engineering, Ltd.,** a Holman Group subsidiary, for the supply of mobile tower scaling carriages and tracked tower drill rigs. In a Derbyshire quarry one of the drills was recently tested in the presence of engineers of the U.S.S.R. Trade Delegation in Great Britain, the accompanying photographs showing the rig in extended working position and fully retracted for travelling.

The rig incorporates four drifters (Holman medium weight S.L. 280 drills mounted on power feed cradles) which can be operated simultaneously by two operators. They are capable of drilling a rock face from ground level up to 32 ft. high and with a horizontal span of 24 ft. The four holes can be drilled simultaneously to a depth of 13 ft. even when angled up to 30°, $2\frac{1}{4}$ in. tungsten-carbide tipped Holbits being used. Drilling speeds of 16 in. per minute are expected. The booms and collapsible tower are hydraulically operated and are remote controlled from panels on the platform above the tower.



Rig in Travelling Position.

The tower itself is mounted on electrically-driven tracks which can negotiate rough and uneven ground and a gradient of 1 in 7 was successfully tackled at the recent tests. Crowding rams of 30 in. stroke are provided so that the feed cradle can be pushed up to the rock face and for movement in confined spaces underground the tower can be collapsed to a height of 11 ft. Electric motors of 40 h.p. and 7½ h.p. are provided for track drive and hydraulic pump drive respectively and a compressed-air supply of approximately 700 c.f.m. is required.



Rig at Work Fully Extended.

Personal

J. BELL, manager of the I.C.I. Nobel Division silicones department since May, 1957, has been appointed to the Division Board in succession to F. B. WRIGHTSON, Engineering and Technical Director, who retired on April 30.

G. W. CRADDUCK, general manager of Halkyn District United Mines, has been appointed a director of the company.

C. W. DANNATT, Professor Emeritus and former Dean of the Royal School of Mines, has been elected a Fellow of the Imperial College.

W. T. DUNNE has been appointed a director of Malayan Tin Dredging and Southern Malayan Tin Dredging.

N. L. FALCON, chief geologist of the B.P. Exploration Company since 1952, has been elected a Fellow of the Royal Society.

ROBERT W. GEEHAN, of Denver, Colorado, has been named regional director of Region III of the United States Bureau of Mines.

S. K. GRICE has left for Northern Rhodesia.

W. J. GUEST, Chief Geologist to the Fiji Survey is home on leave until September.

B. K. HALL is returning from Sierra Leone on leave.

HERMAN HARTJENS has been appointed technical representative for the mining chemicals department of Cyanamid International in South America, with headquarters in Lima, Peru.

P. M. HOLMAN, chairman and joint managing director of Holman Bros., Ltd., has relinquished his office of joint managing director, but is to remain on the board and will continue as chairman. J. F. HOLMAN is now managing director of the company.

F. H. JAQUES is home from Ghana.

LINUS PAULING, of the California Institute of Technology, has accepted an invitation from the Metal Physics Committee of the Institute of Metals to lecture on " The Structure of Metals and Intermetallic Compounds " during his forthcoming visit to Britain.

Sir RONALD L. PRAIN, chairman of the Rhodesian Selection Trust Group of Companies, has relinquished the chairmanship of the Management Committee of the Copper Development Association after ten years in that office. He has been succeeded by Mr. E. C. BARING, a director of the Anglo American Corporation of South Africa, Ltd., and vice-chairman of the Council of the Association, of which Sir Ronald will remain chairman.

Sir WILLIAM PUGH, Director of the Geological Survey and Museum, has been elected a Fellow of the Imperial College.

JOHN W. SEMMENS is home from Mexico.

G. W. THOMAS is now in Northern Rhodesia.

HARRY HEY, chairman of EZ Industries, Ltd., and chairman and managing director of the Electrolytic Zinc Co. of Australasia, Ltd., died on April 11.

CHARLES ALFRED EDWARDS, who died on March 29, aged 78, was Professor of Metallurgy in University College, Swansea, from 1920 to 1947 and Principal of the College from 1927 to 1947. Trained as an engineer Dr. Edwards was from 1905 to 1907 an assistant in the metallurgical department of the National Physical Laboratory, Teddington, and then went north on his appointment as a lecturer in the University of Manchester. After four years from 1910 with Bolckow, Vaughan and Company and Dorman Long, he returned to Manchester as Professor of Metallurgy. In 1927 he succeeded Dr. Sibly as Principal of University College, Swansea. Three years later he was elected F.R.S.

JOHN HOWARD FENNELL, who died on February 4, in his 80th year, took his Associateship in mining from the Royal School of Mines in 1902 and for some years worked on copper properties in Spain and the United States until, in 1912, he went to Nigeria to manage Hausa (Nigeria), Ltd. However, after a brief stay in Nigeria and then in Malaya Mr. Fennell returned to serve with the Forces in the 1914–1918 war and after demobilization in 1919 he worked for the next eight years in Spain again, at Huelva. Thereafter Mr. Fennell devoted his time to examination and consulting work until his retirement in 1943. A Member of the Institution of Mining and Metallurgy Mr. Fennell will be remembered for his keen interest in the strict interpretation of ore reserves.

STANLEY ROBSON, a past-president of the Society of Chemical Industries, the Institution of Chemical Engineers, and the Institution of Mining and Metallurgy, died on March 26, aged 72. Mr. Robson was trained at Armstrong College and took his M.Sc. in Durham University before going to work with Professor Bone at the Imperial College. In 1923 he became connected with the National Smelting Co. and was concerned with the rehabilitation of the Avonmouth and Swansea smelters. He was works director of the Imperial Smelting Corporation until 1945, when for two years he was their director of research and development. In 1947 he became consultant to the Zinc Corporation giving up that appointment in 1953 in order to devote his time to the honorary secretaryship of the Royal Institution.

Metal Markets

During April [1]

Copper.—The copper market was just as unsettled in April as in March. The nearby position remained tight throughout the month, with the sustained high level of consumption and new demand in countries other than the United States absorbing all available metal, so that the prospective surplus of production over consumption at a later stage in the year had initially scant chance to make itself noticed. Consumption in the United States continues to make a rather poorer showing than elsewhere so far this year, but for all that producers have been content to maintain their price at the 33 cents per lb. level ruling at the beginning of April. London Metal Exchange stocks have been sufficiently low throughout the month to discourage short selling.

Of all the up and down price movements [2] on the London Metal Exchange during the month (mainly up) the most marked was undoubtedly on April 25, when cash values leaped £8 10s. a ton on the news of further falls in L.M.E. warehouse stocks, which came at a time when fears of a general stoppage in the Chilean copper industry on May 2 were at their greatest.

Basically, however, the market is performing its first function of reflecting the forward position of the metal. The fact that prices did not leap further ahead when the Chilean strike eventually broke out on the date mentioned is because the overriding consideration is that copper supplies now seem more likely than at any time this year to overtake demand. This is, of course, subject to the Chilean strike not proving a major one, but fears of this are not great at present.

U.K. copper consumption in February amounted to 61,587 tons, of which 48,824 tons was refined. Production of primary refined metal in this country in the same month totalled 7,785 tons and secondary 9,127 tons. Stocks of refined copper at the end of February amounted to 45,134 tons, against 49,875 tons at the end of January. Blister stocks were also down at 10,845 tons as compared with 11,213 tons the previous month.

Tin.—Overall tin consumption these days is quite good, although there has been some surprise expressed in recent weeks at the low level of United States buying when it is remembered that the U.S. tinplate industry continues to operate at a high rate. In the first half of April the market showed few features of any significance, with prices for the most part hovering between £790 and £794 a ton though the backwardation was inclined to vary from day to day according to the actual demand for spot metal.[2] Reduced demand just before Easter caused the market to develop a softer tone, but this grew firmer again after the holiday. The Buffer Stock Manager's withdrawal as a seller of cash tin towards the end of the month, coupled with con-

[1] Recent prices, pp. 272, 312.

[2] See Table, p. 312.

tinued good demand from consumers, resulted in the spot price moving up quite sharply to a peak of £790 a ton, although an easier tone developed again at the very end of the month due, no doubt, to the cautious mood which always makes itself felt when an International Tin Council meeting to consider quotas is in the offing. However, although the market took on a cautious appearance, it was felt reasonably confident by most observers that quotas would be unchanged for a third quarter when fixed at the meeting scheduled to begin on May 2. This meeting (in progress at the time of writing) is rather earlier than is usual for fixing the third-quarter quotas, but this is due, of course, to the impending United Nations Meeting at the end of the month to discuss the renewal of the International Tin Agreement next summer.

U.K. tin consumption in February was only one ton more than in January at 1,879 tons. Production of new metal amounted to 2,144 tons, as compared with 2,377 tons in January. Stocks at February 29 totalled 10,240 tons, against 10,884 tons at the end of January.

Lead.—The lead market has made a good showing in recent weeks and April prices [1] have never been below the 175 mark, while at one time thay were up to £78. Throughout the month consumption continued to run at a good rate both in the U.K. and on the Continent and there is every prospect that it will continue to do so, at least for some little time to come. Even the latest Government measures to restrict credit in this country, which will probably affect the motor industry more than any other, are not thought likely to have much effect on lead consumption for batteries.

Alongside this comfortable picture, however, must be set the fact that it is largely dependent on the maintenance of producers' voluntary restrictions on supplies. At present they are due to last until the end of the third quarter, but some observers have recently begun to express misgivings that if the present trend is continued prices may soon reach levels at which they could prove detrimental to producers' long-term interests. It is interesting that such views should be expressed at present when many people have long been thinking in terms of £80 a ton as the sort of price level that may ultimately be attained as a result of the continuation of restrictions. It is also interesting that any fears about the outcome of the present policy should come to light at a time when its desired effects are only just beginning fully to make themselves felt. It has taken nearly a year for the restrictions to take effect in the main, because until now producers have always had large quantities of metal "in the pipeline." Now that such stocks have become depleted consumers are having to rely at last on the quantities being shipped under the restrictions.

Lead stocks at the end of February were again down, at 42,043 tons as compared with 44,290 tons the previous month. Of the February figure 34,512 tons were imported and 7,531 tons English refined. Production in February amounted to 7,253 tons, against 7,729 tons in January.

Zinc.—Zinc, like lead, continues to be in good demand and prices [1] throughout April have been firmly maintained at levels above £90 a ton—a state of affairs few people would have imagined possible or even dared to hope for only three months ago.[1] Certainly no one would have expected metal to be in fairly tight supply once the producers' voluntary restrictions were lifted, but such has been the case on the London market more than once in recent weeks, although few, if any, consumers appear to have actually gone short. Prospects for continued high demand in the next few weeks still appear good, but, so far as this country is concerned, the latest Government measures to tighten up on credit facilities make the outlook a little more obscure than of late.

The only other big market event of the month was the voicing of the possibility that dealings under the new lead and zinc contracts recently approved by the London Metal Exchange may begin on June 1 for daily prompts on and after October 1. Whenever the new contracts come into force there will be a period of overlap, of course, when dealings on the basis of present contracts will still apply. However, according to traders concerned with international period contracts for lead and zinc concentrates—particularly the latter—the confusion that is likely to ensue during such a period of overlap can best be minimized by introducing the new contracts on January 1, since most ore contracts are already on a calendar year basis.

Zinc stocks were slightly higher at the end of February (48,689 tons, against 48,337 tons the previous month). Of this total consumers held 20,356 tons. Production was again down on the previous month (5,214 tons, as compared with 6,538 tons in January).

Iron and Steel.—The British steel industry continues to operate under very favourable conditions. Production is running at capacity levels and records are being set up at regular intervals. Consumers have maintained their keen interest in supplies of steel and in a few cases are confronted with shortages. Deliveries for most products are lengthening.

Sheet steel is still the most sought after product. The motor industry's high level of production is a major factor in this market, while other sheet users are also anxious to secure material. Despite the maximum outputs from home mills many sheet users are compelled to seek supplementary tonnages from abroad. Sheet imports have been at a staggering rate this year, averaging nearly 50,000 tons a month in the first quarter.

There is a lively call for most other light steel products (strip, tinplate, galvanized sheets, small bars and sections, wire, etc.), while the heavy mills are also working at top pressure to meet the increased requirements for plates and heavy constructional material. Semis supplies are tight and some imports have been made recently.

A few grey spots persist, however. The flow of orders from the shipbuilding, coal mining, and railway industries is somewat restricted. Whereas the plate and section producers are being well supported by other heavy steel users, the railway equipment makers are facing difficult times indeed.

The rapid increase in steel production has created huge demands for scrap and pig iron. The melting shops are taking up all available supplies of scrap, but could take much more, while the production of pig-iron has been raised to record levels.

The export market is proving to be a good outlet for iron and steel. Shipments in the first quarter increased by nearly a third to reach 933,994 tons. Overseas buyers continue to take large tonnages of British tinplate—first quarter exports amounted to 147,585 tons—while tubes and pipes, plates, and

[1] See Table, p. 312.

angles, shapes and sections are also leaving this country in considerable quantities.

Iron Ore.—Production of pig-iron (as already stated) is running at record levels and iron-ore requirements have naturally been stepped up. Supplies of home ore in the first two months of the year (latest figures available) rose to an average of 327,900 tons a week, from 274,900 tons a week in the same two months of last year. Arrivals of imported ore have been at a high rate for the past few months and in the first quarter they jumped to 4,045,284 tons from 2,784,025 tons in the corresponding quarter a year ago.

Aluminium.—In the U.K. aluminium market the big event of the month was the all-round increase in aluminium and aluminium semis prices introduced by leading producers at varying dates from April 11 to April 18, inclusive. The last such rise was in mid-January. This latest increase, by ½d. or 1d. a lb. generally (although a few prices have been raised by 1½d. or more), is a direct consequence of the recent award to engineering workers in the industry of a shorter working week without any reduction in wage rates.

The increase is intended to offset the operating costs resulting from the award. There have been a number of such increases in recent years—indeed every time wages have gone up (and the grant of a shorter working week is, of course, only an indirect means of increasing pay scales) there has been a compensatory rise, just as there has after every increase in primary ingot prices. All of which drives home the tightness of profit margins in the industry—a tightness which could become even more acute as competition gets hotter, as it will, undoubtedly, now that United States interests have begun taking a firm hold on the market.

Underlining the strength of the U.K. aluminium market at present is the high rate of imports into this country in the three months ended March 31. Total aluminium and aluminium alloy imports in that period amounted to 100,452 tons, against only 58,203 tons in the first three months of 1959.

Antimony.—The antimony market continued steady in April and prices in this country remained unchanged from those ruling at the end of March. English regulus 99·6% continues to be quoted at £197 10s. a ton, while 99% is again quoted at £190. In the United States the National Lead Co. increased its various antimony oxide quotations early in the month by 2 cents a lb. all round—the first time there has been a change in U.S. quotations for more than two years.

Arsenic.—It was reported mid-way through April that U.S. consumption of arsenic reached an all-time high in 1959 and that, according to one source, the market in that country is growing steadily. The U.K. market again showed no new features in April and prices remained at £400 a ton for arsenic metal and £40 to £45 a ton ex store for the trioxide.

Bismuth.—Trading in bismuth has been devoid of any outstanding features for some time past and the published quotation is still a nominal 16s. a lb.

Cobalt.—After the recent easing of prices (reported last month) April was a quiet month for cobalt, with open-market metal in the U.K. again quoted throughout at 12s. a lb. delivered. The U.K. contract price remained at 10s. 9d. a lb. and the black and grey oxides, delivered, were quoted once more at 7s. 10d. and 8s. 4d. a lb. respectively.

The softer tone of the market in recent weeks has been due to the availability of rather more metal than for quite some time past. It is now reported that world output in 1959 was a record, at an estimated 17,700 short tons and that additional gains are likely this year—factors which could result in further easier sentiment in the coming months.

Cadmium.—The cadmium market has shown no new features recently following price advances announced in mid-March (see last month's report). U.K. and Empire refined metal in 1-cwt. lots continues to fetch 10s. 6d. a lb. without difficulty, while foreign metal still commands a premium at 10s 6d. to 10s. 9d.

Chromium.—Chromium metal was just as featureless in April, marketwise, as it has been for some months past and quotations are still in the range 6s. 11d. to 7s. 4d. lb. for metal of 96% to 99% purity.

Tantalum.—Tantalum ore is now selling in quite reasonable quantity at 700s. to 750s. a unit, the price established early in March when demand showed some improvement over that of past months.

Platinum.—The platinum market maintained a steady tone throughout April with U.K. and Empire refined metal still selling at £30 5s. a troy oz. and open-market platinum again quoted at £28 to £28 10s. In the United States a change in its platinum trading rules has been announced by the New York Mercantile Exchange. Beginning with the October, 1960, contract all future trading will have trading in the delivery month contract until the 14th day and deliveries only from the 15th onwards.

Iridium.—Iridium sponge and powder continues to sell at prices varying from £23 to £26 15s. a troy oz., with the main established suppliers having little or no difficulty in getting the top price.

Palladium.—Palladium is another metal in which there was no significant market change in April. Prices were again at their end-March levels of £8 10s. to £9 7s. 6d. per troy oz.

Osmium.—Osmium was again priced at a nominal £22 to £32 5s. a troy oz.

Tellurium.—United States and Canadian tellurium producers have been at pains recently to assure consumers that there is no impending shortage. They estimate that annual production in the western hemisphere can be raised to 500,000 to 750,000 lb. a year using only present resources and that 1,000,000 lb. could be refined from the muds and residues hitherto accumulated by refiners—none of which has been taken into account in official figures for reserves or potential production figures. Their statement, issued towards the end of April, was intended "to counteract growing rumours of an impending shortage"—rumours which have previously had implicit confirmation in a rise in prices from $1·65 to $3 per lb. In the U.K. tellurium lump and powder was quoted throughout the month at 21s. 6d. to 25s. a lb. Tellurium sticks were unchanged in price at 30s. a lb.

Tungsten.—Trading in tungsten ore at the beginning of the month was quiet and the weak undertone at the end of March prevailed for some little time before business picked up. Thereafter there were a number of sales at c.i.f. prices around 150s. a long ton unit and the market became rather firmer with the approach of the Easter holiday. Some traders reported a certain tightening of the supply situation mid-way through the month when consumer interest suddenly switched from Europe to the East—notably Japan. The Board of Trade

self-imposed monthly quota of 80 tons was all disposed of at this juncture and the market seemed set to continue firm for the rest of the month. At the beginning of the last week, however, reports of a cheap sale to the Continent caused sentiment to weaken and prices dropped to the range 145s. to 152s. a unit—a level which they held to the end of the month.

Nickel.—The biggest event in the nickel market in April was undoubtedly the speech by the chairman of the International Nickel Co. of Canada in Toronto in April 27, in which he told shareholders that demand for the remainder of this year would continue high. After his company's extraordinarily high rate of deliveries in the first two months March deliveries had fallen off, but total deliveries in the first quarter had certainly exceeded production in the same period. On the other hand, as a further assurance to those who have recently been voicing their fears of a possible shortage, he stressed that future demand could be more than satisfied by the industry's increased productive facilities and by available supplies. Refined nickel is still quoted at £600 a ton delivered.

Chrome Ore.—Price competition in chrome ore in recent weeks has resulted in some shading as regards published c.i.f. U.K. prices. Rhodesian metallurgical, for instance, has been reduced from £15 15s. a ton to £15 5s. Other grades of Rhodesian ore have been reduced further and Transvaal concentrates (46%) previously quoted at £9 2s. 6d. are now quoted at £8 5s. Quotations for Turkish metallurgical (f.o.b.) have remained at $33·5, although this figure has long been largely nominal.

In the first half of the month the U.S. Department of Agriculture announced revised terms for its proposed wheat barter with Turkey. As had already been foreshadowed, it is now prepared to take ferro-chrome instead of chrome ore in exchange for its surplus wheat, provided the processing is done in Turkey or other friendly foreign countries from ore of Turkish origin. Japan is reported to be already actively seeking a proportion of the processing business.

Molybdenite.—Some fears have been expressed in recent months that supplies of molybdenite might become relatively tight since consumption has increased sharply in the last half year or so. More recently there have been signs that the rate of demand is accelerating. However, observers are now coming round to the opinion that the present rate of buying is, if anything, almost overdue for a slow-down, even if consumption is maintained. Unless there is any panic buying or something similar it is confidently expected, by some observers at least, that the first half of this year will show a small surplus of supplies over requirements even though the level of first-quarter deliveries to the Continent will almost certainly constitute a record and may even be up to the actual level of consumption. On the year as a whole both Europe and elsewhere are expected to be amply supplied. American Climax material f.o.b. mine is again quoted at 8s. 11d. per lb of Mo contained. Material from other sources still fetches 9s. 3½d. a lb c.i.f.

Manganese Ore.—The manganese ore market has been featureless in recent weeks and there has certainly been nothing to lift it from the depressed state of past months. In consequence there has been no change from the nominal 68d. to 73d. quoted as the c.i.f. Europe value for 46% to 48% ore.

Tin, Copper, Lead, and Zinc Prices

Tin, minimum, 99·75%; Copper, electro; Lead, minimum 99·75%; and Zinc, minimum 98%, per ton.

Date	Tin		Copper		Lead		Zinc	
	Settlement	3 Months	Spot	3 Months	Spot	3 Months	Spot	3 Months
	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.
Apr. 8	794 0	786 5	258 12½	241 17½	77 16¼	76 16¼	92 7½	89 18¾
11	788 10	785 10	258 10	241 17½	77 7½	76 7½	92 2½	89 7½
12	787 0	784 15	261 15	241 15	76 17½	76 1¼	92 2½	89 2½
13	787 10	784 15	264 5	243 15	76 18¾	76 3¾	92 2½	89 2½
14	788 0	784 15	266 5	244 17½	77 8¾	76 13¾	92 2½	89 7½
15	—	—	—	—	—	—	—	—
18	—	—	—	—	—	—	—	—
19	787 10	784 5	265 5	245 2½	77 12½	76 13¾	92 2½	89 7½
20	788 10	783 15	264 15	245 15	77 16¼	76 18¾	92 2½	89 7½
21	788 10	783 15	268 7½	248 12½	77 13¾	76 18¾	92 12½	89 17½
22	791 0	785 5	271 12½	249 17½	77 11¼	76 16¼	92 13¾	89 18¾
25	797 0	785 15	279 5	254 5	77 10	76 13¾	92 16¼	89 18¾
26	797 0	785 10	270 10	248 15	77 7½	76 7½	93 2½	90 2½
27	798 0	785 5	266 0	249 5	77 15	76 11¼	93 10	90 7½
28	794 0	784 5	259 15	246 15	77 13¾	76 13¾	94 2½	90 17½
29	791 0	782 15	259 0	247 5	77 13¾	76 7½	93 17½	90 17½
May 2	784 0	778 10	258 15	246 5	76 18¾	76 2½	92 13¾	90 8¾
3	786 0	781 10	262 10	249 5	77 3¾	76 7½	93 13¾	91 7½
4	792 0	787 10	263 10	249 5	77 3¾	76 6¼	94 1¼	91 17½
5	791 10	787 5	258 15	246 7½	77 6¼	76 8¾	94 1¼	91 17½
6	789 10	785 5	249 15	242 15	77 13¾	76 16¼	92 15	91 2½
9	787 0	784 0	248 10	242 15	77 8¾	76 8¾	92 11¼	91 2½
10	785 0	783 5	250 15	244 15	77 11¼	76 10	92 7½	91 12½

Statistics

TRANSVAAL AND O.F.S. GOLD OUTPUTS

	Mar.		April	
	Treated Tons	Yield Oz.*	Treated Tons	Yield Oz.*
Blyvooruitzicht	126,000	82,206	121,000	80,496
Brakpan	146,000	17,380	143,000	17,318
Buffelsfontein‡	130,000	51,402	145,000	57,420
City Deep	113,000	24,008	109,000	22,841
Cons. Main Reef	70,000	14,734	63,000	13,149
Crown Mines	206,000	32,424	186,000	31,529
Daggafontein	232,000	46,650	233,000	47,189
Dominion Reef	—	—	44,000	350
Doornfontein‡	93,000	38,016	100,000	40,510
D'rb'n Roodeport Deep	196,000	35,734	186,000	34,330
East Champ D'Or‡	12,000	286	12,500	310
East Daggafontein	105,000	17,851	107,000	18,192
East Geduld	139,000	40,658	129,000	38,055
East Rand P.M.	228,000	57,755	200,000	53,018
Eastern Transvaal Consol	18,900	6,393	19,100	6,557
Ellaton‡	26,000	6,196	29,000	6,818
Freddies Consol.	56,000	12,746	56,000	12,802
Free State Geduld	90,000	77,626	95,000	81,956
Geduld	75,000	13,510	70,000	12,605
Government G.M. Areas‡	54,000	11,080	52,000	10,809
Grootvlei Proprietary	220,000	45,873	210,000	43,686
Harmony Gold Mining	149,000	59,832	151,000	61,156
Hartebeestfontein‡	100,000	47,000	120,000	55,800
Libanon	112,000	26,631	117,000	27,675
Loraine	67,000	14,238	81,000	17,213
Luipaards Vlei‡	120,000	13,456	120,000	13,487
Marievale Consolidated	102,000	24,888	96,000	23,616
Modderfontein East	141,000	13,413	131,000	12,707
New Kleinfontein	81,000	10,720	75,000	10,155
New Klerksdorp‡	10,300	1,255	11,300	1,284
President Brand	110,000	89,101	120,000	97,131
President Steyn	95,000	36,859	105,000	40,395
Rand Leases	177,500	26,591	185,000	28,028
Randfontein‡	182,000	12,367	183,000	12,938
Rietfontein Consolid't'd.	16,000	4,178	16,000	4,210
Robinson Deep	45,000	9,801	45,000	10,172
Rose Deep	27,000	4,355	22,000	3,852
St. Helena Gold Mines	150,000	50,255	158,000	53,727
Simmer and Jack	78,000	13,971	76,000	13,488
S. African Land and Ex.	96,500	20,024	97,000	20,129
S. Roodepoort M.R.	30,000	7,069	29,000	6,909
Spaarwater Gold	11,000	3,388	10,700	3,355
Springs	102,000	14,353	102,000	14,280
Stilfontein Gold Mining‡	147,000	66,200	162,000	72,900
Sub Nigel	66,500	15,252	66,500	15,225
Transvaal G.M. Estates	7,700	1,883	6,800	1,694
Vaal Reefs‡	90,000	28,441	98,500	44,325
Van Dyk Consolidated	76,000	12,821	70,000	11,794
Venterspost Gold	109,000	28,177	130,000	33,586
Village Main Reef	30,400	4,713	30,200	4,687
Virginia O.F.S.‡	120,000	26,700	136,000	29,240
Vlakfontein	52,000	18,474	52,000	18,440
Vogelstruisbult‡	86,000	18,383	85,000	18,343
Welkom Gold Mining	90,000	28,441	100,000	31,522
West Driefontein‡	112,000	102,992	130,000	120,097
West Rand Consol.‡	198,000	19,174	209,000	21,274
Western Holdings	144,000	96,120	150,000	100,056
Western Reefs	131,000	36,877	144,000	40,608
Winkelhaak	83,000	25,730	83,006	25,731
Witwatersrand Nigel	19,400	4,403	19,500	4,383

† 249s. 8d. * 249s. 5d. ‡ Gold and Uranium.

COST AND PROFIT IN THE UNION

	Tons milled	Yield per ton	Work'g cost per ton	Work'g profit per ton	Total working profit
		s. d.	s. d.	s. d.	£
Mar., 1959	16,743,500	68 0	45 4	22 8	25,934,881
April	—	—	—	—	—
May	—	—	—	—	—
June	17,845,100	69 1	45 2	23 11	28,473,191
July	—	—	—	—	—
August	—	—	—	—	—
Sept.	18,214,200	70 5	45 2	25 3	30,140,529
Oct.	—	—	—	—	—
Nov.	—	—	—	—	—
Dec.	17,670,000	72 2	45 10	26 4	30,559,937
Jan., 1960	—	—	—	—	—
Feb.	—	—	—	—	—
Mar.	—	—	—	—	30,105,571

* 3 Months.

PRODUCTION OF GOLD IN SOUTH AFRICA

	Rand and O.F.S.	Outside	Total
	Oz.	Oz.	Oz.
April, 1959	1,616,891	36,815	1,653,706
May	1,641,990	30,371	1,672,361
June	1,695,503	34,465	1,699,968
July	1,700,968	48,414	1,749,382
August	1,699,098	36,052	1,735,150
September	1,701,485	36,567	1,738,052
October	1,718,916	33,576	1,752,492
November	1,688,379	34,903	1,723,282
December	1,662,043	31,309	1,693,352
January, 1960	1,701,110	34,651	1,735,761
February	1,675,248	38,859	1,714,107
March	1,664,514	38,744	1,703,258

NATIVES EMPLOYED IN THE SOUTH AFRICAN MINES

	Gold Mines	Coal Mines	Total
July 31, 1959	381,190	33,295	414,485
August 31	377,257	32,994	410,251
September 30	371,813	32,903	404,716
October 31	365,833	32,567	398,400
November 30	358,746	32,067	390,813
December 31	354,058	31,993	386,021
January 31, 1960	372,254	31,993	404,247
February 29	385,027	32,144	417,171
March 31	388,860	30,696	419,556

MISCELLANEOUS METAL OUTPUTS

	4-Week Period To April		
	Tons Ore	Lead Concs. tons	Zinc Concs. tons
Broken Hill South	26,850	4,116	5,271
Electrolytic Zinc	13,296	720	3,766
Lake George	16,005	1,436	2,745
Mount Isa Mines**	52,908	3,530†	2,473
New Broken Hill	54,550	7,281	13,469
North Broken Hill	30,355	6,393	7,418
Zinc Corp.	60,080	9,385	11,065
Rhodesia Broken Hill*	—	3,548†	7,380†

* 3 Months. ** Copper 3,000 tons. † Metal.

RHODESIAN GOLD OUTPUTS

	March		April	
	Tons	Oz.	Tons	Oz.
Cam and Motor	—	—	—	—
Falcon Mines	20,000	3,850	20,400	3,937
Globe and Phœnix	6,100	3,027	6,100	3,329
Motapa Gold Mining	—	—	—	—
Mazoe	3,120	—	3,157	—
Coronation Syndicate	12,277	—	12,093	—
Phœnix Prince*	48,870	3,796	—	—

* 3 Months.

WEST AFRICAN GOLD OUTPUTS

	March		April	
	Tons	Oz.	Tons	Oz.
Amalgamated Banket	59,095	13,210	60,214	13,025
Ariston Gold Mines	40,500	13,307	40,350	13,372
Ashanti Goldfields	35,500	29,650	35,000	29,550
Bibiani	33,000	7,100	32,000	7,050
Bremang	—	6,400	—	5,043
Ghana Main Reef	11,978	4,153	11,267	4,479
Konongo	7,200	3,562	7,220	3,580
Lyndhurst	—	—	—	—

PRODUCTION OF GOLD AND SILVER IN RHODESIA

	1959		1960	
	Gold (oz.)	Silver (oz.)	Gold (oz.)	Silver (oz.)
January	46,489	18,077	44,902	29,711
February	43,366	19,806	—	—
March	48,397	17,394	—	—
April	—	—	—	—
May	46,423	46,280	—	—
June	49,995	31,386	—	—
July	46,512	32,734	—	—
August	38,727	29,178	—	—
September	56,760	33,837	—	—
October	48,528	32,314	—	—
November	47,916	31,092	—	—
December	47,452	31,175	—	—

WESTRALIAN GOLD PRODUCTION

	1958	1959	1960
	Oz.	Oz.	Oz.
January	66,562	63,924	64,794
February	65,965	65,035	66,789
March	65,420	65,408	61,941
April	60,855	62,686	—
May	64,196	64,184	—
June	67,929	74,590	—
July	81,106	78,974	—
August	68,610	—	—
September	68,744	—	—
October	70,128	70,427	—
November	67,562	68,858	—
December	120,106	117,474	—
Total	867,187	861,122	—

AUSTRALIAN GOLD OUTPUTS

	4-Week Period			
	To Mar. 29		To April 26	
	Tons	Oz.	Tons	Oz.
Central Norseman	13,981	7,359	14,118	6,852
Gold Mines of Kalgoorlie	41,093	11,664	41,508	11,347
Gt. Boulder Gold Mines*	—	—	—	—
Gt. Western Consolidated	31,380	41,397	30,312	4,504
Lake View and Star*	72,352	38,646	—	—
North Kalgurli	—	—	—	—
Sons of Gwalia	11,018	2,131	12,188	2,094
Mount Morgan	—	4,768	—	—

* 3 Months.

ONTARIO GOLD AND SILVER OUTPUT

	Tons Milled	Gold Oz.	Silver Oz.	Value Canad'n $
November, 1958	783,065	230,251	35,097	7,842,435
December	787,573	219,351	30,989	7,490,094
January, 1959	799,178	227,656	41,277	7,700,672
February	727,843	227,981	32,976	7,798,523
March	807,952	223,728	33,045	7,616,425
April	776,583	225,027	32,778	7,712,425
May	791,199	227,924	34,006	7,713,970
June	768,725	213,486	31,692	7,178,823
July	774,749	221,814	32,172	7,498,030
August	683,819	191,598	29,141	6,428,545
September	754,208	213,772	34,139	7,116,556
October	794,030	227,192	34,733	7,558,567
November	770,437	227,176	35,262	7,600,949
December	775,803	221,377	40,807	7,388,654
January, 1960	778,103	226,856	27,617	7,550,068
February	755,569	222,484	35,003	7,446,848

MISCELLANEOUS GOLD AND SILVER OUTPUTS

	Mar.		April	
	Tons	Oz.	Tons	Oz.
Clutha River	—	337	—	306
Lampa (Peru)†	—	36,278	—	33,043
New Guinea Goldfields	4,311	1,310	4,073	1,068
Yukon Consol.	—	—	—	—

† Oz. Silver : Copper, 83 tons ; 92.

AUSTRALIAN BASE-METAL OUTPUTS

Period	Concentrate Production (Long Tons)		
	Zinc	Copper (*a*)	Lead
1959	246,693	89,162	305,163
Provisional 1959—January	12,946	7,744	14,874
February	23,658	8,493	25,836
March	—	—	—
April	—	—	—
May	—	—	—
June	—	—	—
July	—	—	—
August	—	—	—
September	—	—	—
October	—	—	—
November	—	—	—
December	—	—	—

(*a*) includes Cu content of direct smelting ore.

OUTPUTS OF MALAYAN TIN COMPANIES IN LONG TONS OF CONCENTRATES

	Feb.	Mar.	April
Ampat Tin	80	68	58½
Austral Amalgamated	—	—	—
Ayer Hitam	—	622*	—
Batu Selangor	—	—	—
Berjuntai	201	216	170
Chenderiang	—	46½*	—
Gopeng Consolidated	—	334½*	—
Hongkong Tin	—	74*	—
Idris Hydraulic	—	53*	—
Ipoh	—	114*	—
Jelapang Tin	—	—	—
Kampong Lanjut	110	95½	81½
Kamunting	154½	170	139
Kent (F.M.S.)	—	56½*	—
Kepong	—	—	—
Killinghall	—	102*	—
Kinta Kellas	33	28	29
Kinta Tin Mines	—	—	—
Klang River	—	—	—
Kramat	68	74	63
Kuala Kampar	62½	76	91
Kuala Lumpur	—	—	—
Kuchai	—	—	—
Lahat Mines	—	—	—
Larut	—	—	—
Lower Perak	205	162	167½
Malayan	—	923*	—
Malaysiam	7	5	—
Pacific Tin Consolidated	—	—	—
Pahang Consolidated	—	594*	—
Pengkalen	—	105½*	—
Petaling Tin	—	334*	—
Puket	—	—	—
Rahman Hydraulic	—	—	—
Rambutan	—	33*	—
Rantau	38	43	42½
Rawang Concessions	—	—	—
Rawang Tin Fields	—	—	—
Renong	—	—	—
Selayang	—	44*	—
Siamese Tin Syndicate (Malaya)	25	20	38
Southern Kinta	219	280	271
Southern Malayan	—	765*	—
Southern Tronoh	—	—	—
Sungei Besi	—	244*	—
Sungei Kinta	—	27½*	—
Sungei Way	—	321½*	—
Taiping Consolidated	—	—	—
Tambah	—	—	—
Tanjong	—	216*	—
Tekka	—	17*	—
Tekka-Taiping	—	—	—
Temoh	—	14*	—
Tongkah Compound	—	—	—
Tongkah Harbour	132	103	108½
Tronoh	—	680½*	—
Ulu Klang	—	—	—

* 3 Months.

MISCELLANEOUS TIN COMPANIES' OUTPUTS IN LONG TONS OF CONCENTRATES

	Mar.		April	
	Tin	Columbite	Tin	Columbite
Amalgamated Tin Mines	304	34	347	—
Anglo-Burma Tin*	46	—	—	—
Bangrin	75	—	85	—
Beralt	6	174†	7	159†
Bisichi	48	32½	42	35
Ex-Lands Nigeria	44	—	42	—
Geevor	55½	—	52	—
Gold and Base Metal	63	6	—	—
Jantar Nigeria	17½	17½	17	17
Jos Tin	11	—	—	—
Kaduna Prospectors	6	—	5	—
Kaduna Syndicate	23	—	26½	—
Katu Tin	15	—	24	—
Keffi Tin	—	—	—	—
London Nigerian Mines	—	—	—	—
Mawchi Mines	—	—	—	—
Naraguta Extended	—	—	—	—
Naraguta Karama	9½	—	8	—
Naraguta Tin	—	—	—	—
Renong Consolidated	—	—	—	—
Ribon Valley (Nigeria)	—	—	—	—
Siamese Tin Syndicate	107	—	119	—
South Bukeru	—	—	—	—
South Crofty	80	—	66	—
Tavoy Tin	—	—	—	—
Tin Fields of Nigeria	—	—	—	—
United Tin Areas of Nigeria	36	½	—	—

* 3 Months. † Wolfram.

SOUTH AFRICAN MINERAL OUTPUT

January, 1960.

Gold	1,738,160 oz.
Silver	176,353 oz.
Diamonds	583,414 carats.*
Coal	3,332,400 tons.
Copper	(*a*) — tons in matte and copper-gold concentrates. (*b*) 5,100 tons of 99·24%.
Tin	tons concs.
Platinum (concentrates, etc.)	205
Platinum (crude)	—
Asbestos	14,273 tons.
Chrome Ore	59,905 tons.
Manganese Ore	84,399 tons.
Lead Concs.	— tons.

* *December, 1959.*

IMPORTS OF ORES, METALS, ETC., INTO UNITED KINGDOM

		Feb.	Mar.
Iron Ore	tons	1,293,403	1,398,768
Manganese Ore	,,	28,309	30,634
Iron and Steel	,,	90,163	105,686
Iron Pyrites	,,	19,075	2,887
Copper Metal	,,	40,075	43,917
Tin Ore	,,	5,072	4,786
Tin Metal	,,	420	10
Lead	,,	13,052	16,125
Zinc Ore and Conc.	,,	8,702	26,848
Zinc	,,	17,616	19,801
Tungsten Ores	,,	662	576
Chrome Ore	,,	16,594	21,749
Bauxite	,,	14,687	28,458
Antimony Ore and Concs.	,,	2,551	1,208
Titanium Ore	,,	56,865	32,416
Nickel Ore	,,	—	—
Tantalite/Columbite	,,	122	100
Sulphur	,,	41,867	45,723
Barytes	,,	5,090	5,880
Asbestos	,,	8,208	9,276
Magnesite	,,	3,502	6,332
Mica	,,	1,009	351
Graphite	,,	1,219	911
Mineral Phosphates	,,	148,888	122,426
Molybdenum Ore	,,	923	690
Nickel	cwt.	2,986	61,716
Aluminium	,,	785,453	644,556
Mercury	lb.	139,981	107,112
Bismuth	,,	50,367	55,250
Cadmium	,,	422,750	302,753
Cobalt and Cobalt Alloys	,,	124,500	139,031
Selenium	,,	22,989	27,374
Petroleum Motor Spirit	1,000 gals.	71,032	97,194
Crude	,,	1,015,734	910,108

Prices of Chemicals

The figures given below represent the latest available.

		£	s.	d.
Acetic Acid, Glacial	per ton	106	0	0
,, ,, 80% Technical	,,	97	0	0
Alum, Comml.	,,	25	0	0
Aluminium Sulphate	,,	16	10	0
Ammonia, Anhydrous	per lb.		2	0
Ammonium Carbonate	per ton	59	0	0
,, Chloride, 98%	,,	28	12	6
,, Phosphate (Mono- and Di-)	,,	102	0	0
Antimony Sulphide, golden	per lb.		2	9
Arsenic, White, 99/100%	per ton	47	0	0
Barium Carbonate 98–99%	,,	42	0	0
,, Chloride	,,	45	0	0
Barytes (Bleached)	,,	20	0	0
Benzene	per gal.		5	2
Bleaching Powder, 35% Cl.	per ton	30	7	6
Borax	,,	46	0	0
Boric Acid, Comml.	,,	77	0	0
Calcium Carbide	,,	40	17	9
,, Chloride, solid, 70/75%	,,	13	5	0
Carbolic Acid, crystals	per lb.		1	6
Carbon Bisulphide	per ton	62	10	0
Chromic Acid (ton lots)	per lb.		2	2½
Citric Acid	per cwt.	9	15	0
Copper Sulphate	per ton	80	0	0
Creosote Oil (f.o.r. in Bulk)	per gal.		1	2
Cresylic Acid, refined	,,		7	0
Hydrochloric Acid 28° Tw.	per carboy		11	6
Hydrofluoric Acid, 59/60%	per lb.		1	1
Iron Sulphate	per ton	3	5	0
Lead, Carbonate, white	,,	122	0	0
,, Nitrate	,,	110	0	0
,, Oxide, Litharge	,,	112	15	0
,, Red	,,	110	15	0
Lime Acetate, brown	,,	40	0	0
Lithopone	,,	57	10	0
Magnesite, Calcined	,,	20	0	0
,, Raw	,,	13	0	0
Magnesium Chloride, ex Wharf	,,	16	0	0
,, Sulphate, Comml.	,,	15	10	0
Methylated Spirit, Industrial, 66 O.P.	per gal.		6	1
Nickel Sulphate	per ton	189	0	0
Nitric Acid, 80° Tw.	,,	32	0	0
Oxalic Acid	,,	132	0	0
Phosphoric Acid (S.G. 1·750)	per lb.		1	4
Potassium Bichromate	,,		1	2½
,, Bromide	,,	11	2	6
,, Carbonate (hydrated)	per ton	74	10	0
,, Chloride	,,	21	0	0
,, Iodide	per kilo		15	3
,, Amyl Xanthate	,,	Nominal		
,, Hydrate (Caustic) flake	per ton	92	0	0
,, Nitrate	per cwt.	4	1	0
,, Permanganate	per ton	198	0	0
,, Sulphate, 50%	,,	20	13	0
Sal-Ammoniac	,,	70	0	0
Sodium Acetate	,,	63	0	0
,, Arsenate, 58–60%	,,	Nominal		
,, Bicarbonate	,,	18	10	0
,, Bichromate	per lb.		1	0
,, Carbonate (Soda Ash) 58%	,,	16	0	0
,, Chlorate	,,	77	0	0
,, Cyanide	per cwt.	6	18	10
,, Hydrate, 76/77%, solid	per ton	33	0	0
,, Hyposulphite, Comml.	,,	35	0	0
,, Nitrate, Comml.	,,	29	0	0
,, Phosphate (Dibasic)	,,	40	10	0
,, Prussiate	per lb.		1	0½
,, Silicate	per ton	11	10	0
,, Sulphate (Glauber's Salt)	,,	9	15	0
,, ,, (Salt-Cake)	,,	10	0	0
,, Sulphide, flakes, 60/62%	,,	38	12	6
,, Sulphite, Comml.	,,	27	15	0
Sulphur, American, Rock (Truckload)	,,	13	0	0
,, Ground, Crude	,,	17	10	0
Sulphuric Acid, 168° Tw.	,,	12	0	0
,, ,, free from Arsenic, 140° Tw.	,,	8	10	0
Superphosphate of Lime, 18% P_2O_5	,,	14	18	6
Tin Oxide	,,	Nominal		
Titanium Oxide, Rutile	,,	172	0	0
,, White, 25%	,,	85	0	0
Zinc Chloride	,,	95	0	0
,, Dust, 95/97% (4-ton lots)	,,	131	0	0
,, Oxide	,,	100	0	0
,, Sulphate	,,	32	0	0

Share Quotations

Shares of £1 par value except where otherwise stated.

GOLD AND SILVER:	Apr. 6, 1960 £ s. d.	May 10, 1960 £ s. d.
SOUTH AFRICA:		
Blinkpoort (5s.)	3 2 6	2 18 9
Blyvooruitzicht (2s. 6d.)	1 5 3	1 4 6
Bracken (10s.)	1 3 6	1 3 6
Brakpan (3d.)	4 6	4 3
Buffelsfontein (10s.)	2 0 0	1 17 6
City Deep	15 6	14 6
Consolidated Main Reef	15 0	14 3
Crown Mines (10s.)	1 1 3	1 1 6
Daggafontein (5s.)	1 0 3	1 0 3
Dominion Reefs (5s.)	12 0	11 8
Doornfontein (10s.)	1 10 3	1 9 3
Durban Roodepoort Deep (10s.)	1 6 0	1 6 6
East Champ d'Or (2s. 6d.)	2 0	1 9
East Daggafontein (10s.)	7 9	8 3
East Geduld (4s.)	19 6	18 0
East Rand Ext. (5s.)	1 0 0	1 0 0
East Rand Proprietary (10s.)	1 11 0	1 10 6
Freddies Consol.	2 0	1 9
Free State Dev. (5s.)	5 6	4 9
Free State Geduld (5s.)	6 15 0	5 17 6
Free State Saaiplaas (10s.)	15 9	12 9
Geduld	2 13 9	2 10 6
Government Gold Mining Areas (3d.)	2 6	2 3
Grootvlei (5s.)	19 6	18 9
Harmony (5s.)	1 10 3	1 8 3
Hartebeestfontein (10s.)	2 12 6	2 8 6
Libanon (10s.)	12 9	12 3
Loraine (10s.)	1 11 3	1 5 6
Luipaards Vlei (2s.)	7 6	7 6
Marievale (10s.)	1 4 3	1 4 3
Modderfontein B (3d.)	2 0	1 9
Modderfontein East	12 9	12 3
New Kleinfontein	3 9	3 9
New Pioneer (5s.)	1 10 0	1 9 3
New State Areas (15s. 6d.)	9	9
President Brand (5s.)	2 16 3	2 15 0
President Steyn (5s.)	1 2 9	1 1 9
Rand Leases (9s. 3d.)	6 6	6 0
Randfontein	18 0	16 6
Rietfontein (3s.)	3 6	3 6
Robinson Deep (5s. 6d.)	5 0	5 0
Rose Deep (3s. 6d.)	9 6	10 0
St. Helena (10s.)	3 5 0	3 3 6
Simmer and Jack (1s. 6d.)	1 3	1 3
South African Land (3s. 6d.)	13 3	13 0
Springs (5d.)	1 6	1 3
Stilfontein (5s.)	1 11 3	1 11 0
Sub Nigel (3d.)	10 0	9 9
Vaal Reefs (5s.)	2 2 6	2 1 9
Van Dyk (3d.)	3 6	3 3
Venterspost (10s.)	17 6	18 0
Virginia (5s.)	4 0	3 9
Vlakfontein (10s.)	16 0	17 0
Vogelstruisbult (3d.)	6 0	5 9
Welkom (5s.)	16 9	14 3
West Driefontein (10s.)	7 18 9	8 2 6
West Rand Consolidated (10s.)	17 6	18 3
West Witwatersrand Areas (2s. 6d.)	2 17 6	2 15 6
Western Holdings (5s.)	6 13 9	5 17 6
Western Reefs (5s.)	1 5 0	1 6 3
Winkelhaak (10s.)	1 1 3	1 0 0
Witwatersrand Nigel (2s. 6d.)	1 0	1 0
Zandpan (10s.)	16 6	15 0
RHODESIA:		
Cam and Motor (2s. 6d.)	—	—
Chicago-Gaika (10s.)	1 2 6	17 6
Coronation (2s. 6d.)	5 3	5 0
Falcon (5s.)	9 6	9 6
Globe and Phœnix (5s.)	1 12 6	1 11 3
Motapa (5s.)	—	—
GOLD COAST:		
Amalgamated Banket (3s.)	1 0	1 0
Ariston Gold (3s. 6d.)	4 6	4 0
Ashanti Goldfields (4s.)	1 0 6	19 9
Bibiani (4s.)	3 0	2 9
Bremang Gold Dredging (5s.)	3 0	2 9
Ghana Main Reef (5s.)	2 9	2 9
Konongo (2s.)	1 6	1 6
Kwahu (2s.)	6 0	6 0
Offin River (2s. 6d.)	3 3	3 6
Western Selection (5s.)	5 6	5 3
AUSTRALASIA:		
Gold Fields Aust. Dev. (3s.), W.A.	1 6	1 6
Gold Mines of Kalgoorlie (10s.)	7 6	7 3
Great Boulder Propriet'y (2s.), W.A.	11 3	11 3
Lake View and Star (4s.), W.A.	1 9 3	1 6 6
Mount Morgan (10s.), Q.	16 0	16 0
New Guinea Gold (4s. 3d.)	2 0	2 0
North Kalgurli (1912) (2s.), W.A.	10 0	10 0
Sons of Gwalia (10s.), W.A.	2 6	2 6
Western Mining (5s.), W.A.	9 6	9 6

	Apr. 6, 1960 £ s. d.	May 10, 1960 £ s. d.
MISCELLANEOUS:		
Fresnillo ($1·00)	1 10 0	1 6 6
Kentan Gold Areas	1 8 9	1 6 9
St. John d'el Rey, Brazil	4 15 0	6 5 0
Yukon Consolidated ($1)	5 2	4 9
COPPER:		
Bancróft Mines (5s.), N. Rhodesia	1 1 9	17 6
Esperanza (2s. 6d.), Cyprus	2 0	2 3
Indian (2s.)	5 0	5 3
MTD (Mangula) (5s.)	10 0	9 6
Messina (5s.), Transvaal	5 7 6	5 4 6
Mount Lyell (5s.), Tasmania	5 3	5 6
Nchanga Consolidated, N. Rhodesia	2 15 9	2 15 0
Rhokana Corporation, N. Rhodesia	2 12 6	2 9 3
Roan Antelope (5s.), N. Rhodesia	6 9	6 6
Tanganyika Concessions (10s.)	1 15 3	1 10 0
LEAD-ZINC:		
Broken Hill South (1s.), N.S.W.	11 9	12 6
Burma Mines (3s. 6d.)	1 6	1 9
Consol. Zinc Corp. Ord.	3 16 3	3 13 0
Lake George (5s.), N.S.W.	3 9	3 9
Mount Isa, Queensland (5s. Aust.)	2 17 9	2 9 6
New Broken Hill (5s.), N.S.W.	2 3 6	2 4 0
North Broken Hill (5s.), N.S.W.	5 17 6	6 0 0
Rhodesia Broken Hill (5s.)	8 6	9 3
San Francisco (10s.), Mexico	18 9	19 0
TIN:		
Amalgamated Tin (5s.), Nigeria	9 9	9 6
Ampat (4s.), Malaya	13 9	14 6
Ayer Hitam (5s.), Malaya	3 12 6	4 5 0
Beralt (5s.), Portugal	1 10 0	1 9 0
Bisichi (2s. 6d.), Nigeria	5 6	5 9
Ex-Lands (2s.), Nigeria	2 6	3 3
Geevor (5s.), Cornwall	1 4 3	1 4 3
Gold Base Metals (2s. 6d.), Nigeria	2 0	1 9
Hongkong (5s.), Malaya	6 3	6 6
Jantar Nigeria (3s.)	4 6	4 6
Kaduna Syndicate (2s.), Nigeria	2 6	2 6
Kamunting (5s.), Malaya	16 3	16 9
Malayan Tin Dredging (5s.)	1 3 0	1 4 9
Mawchi Mines (4s.), Burma	1 6	1 3
Naraguta Extended (5s.), Nigeria	1 6	1 6
Pahang (5s.), Malaya	10 3	9 9
Ribon Valley (2s.), Nigeria	9	9
Siamese Synd. (5s.)	11 6	13 0
South Crofty (5s.), Cornwall	5 6	4 6
Southern Kinta (5s.), Malaya	1 7 6	1 9 3
Southern Malayan (5s.)	18 9	18 6
Southern Tronoh (5s.), Malaya	14 0	13 6
Sungei Besi (4s.), Malaya	1 2 0	1 4 0
Sungei Kinta, Malaya	17 6	16 6
Tekka (12s. 6d.), Malaya	7 6	9 9
Tronoh (5s.), Malaya	1 12 6	1 14 9
DIAMONDS:		
Anglo American Investment	12 1 3	11 15 0
Consol African Selection Trust (5s.)	1 5 0	1 3 0
Consolidated of S.W.A. Pref. (10s.)	9 9	10 3
De Beers Deferred (5s.)	7 5 0	6 13 9
FINANCE, Etc.		
African & European (10s.)	3 7 9	3 7 6
Anglo American Corporation (10s.)	7 16 3	7 10 0
Anglo Transvaal 'A' (5s.)	2 1 3	1 18 9
British South Africa (15s.)	4 1 9	3 19 6
British Tin Investment (10s.)	1 10 6	1 7 6
Broken Hill Proprietary	3 4 0	3 7 6
Camp Bird (10s.)	10 6	8 9
Central Mining	3 6 6	3 7 0
Central Provinces Manganese (10s.)	1 14 3	1 12 9
Consolidated Gold Fields	3 6 3	3 1 6
Consolidated Mines Selection (10s.)	1 12 6	1 10 0
Corner House	16 9	14 3
East Rand Consolidated (5s.)	2 0	2 0
Free State Development (5s.)	5 3	4 9
General Exploration O.F.S. (2s. 6d.)	4 3	3 9
General Mining and Finance	4 12 6	4 15 0
Hendersons (4s.)	11 0	9 9
Johannesburg Consolidated	2 13 9	2 10 0
London & Rhod. M. & L. (5s.)	6 3	6 0
London Tin Corporation (4s.)	11 0	11 3
Lydenburg Est. (5s.)	14 3	13 6
Marsman Investments (10s.)	2 6	1 9
National Mining	2 3	2 3
Rand Mines (5s.)	3 8 9	3 7 6
Rand Selection (5s.)	2 10 0	2 7 0
Rhodesian Anglo American (10s.)	3 11 6	3 4 3
Rhodesian Corporation (5s.)	3 0	3 0
Rhodesian Selection Trust (5s.)	12 3	11 6
Rio Tinto (10s.)	1 17 6	1 13 0
Selection Trust (10s.)	4 12 6	4 8 9
South West Africa Co. (3s. 4d.)	16 0	16 0
Union Corporation (2s. 6d.)	2 16 3	2 10 0
Vereeniging	5 5 0	4 17 6
West Rand Inv. Trust (10s.)	2 10 0	2 8 9

THE MINING DIGEST

A RECORD OF PROGRESS IN MINING, METALLURGY, AND GEOLOGY

In this section abstracts of important articles and papers appearing in technical journals and proceedings of societies are given, together with brief records of other articles and papers; also notices of new books and pamphlets and lists of patents on mining and metallurgical subjects.

Self-Fluxing Pellets from Taconite

A paper by K. E. Merklin and F. D. DeVaney in *Mining Engineering* for March describes the "Production of Self-Fluxing Pellets in the Laboratory and Pilot Plant." The authors points out that to yield a suitable concentrate the Minnesota magnetic taconites must be ground to about 80% through 325 mesh, too fine to be charged directly to the blast-furnace or to make acceptable feed to the sinter strand. The pelletizing process was developed to meet the structure requirements laid down by the blast-furnace operators, but taconite producers are succeeding in their efforts just when the attention of the blast-furnace man is being drawn to the great advantages of self-fluxing sinter.

After the taconite has been ground to about 80% through 325 mesh to liberate the magnetite grains the ore is concentrated on magnetic separators, thickened, and filtered to about 10% moisture. This structure and moisture fit closely with the conditions required to produce good balls. It has been found with taconite concentrates that at least 60% of the feed to the balling drum must be *minus* 325 mesh to obtain good ball compaction within reasonable time. The filter cake moisture usually permits a slight water addition at the balling drum and further balling control is obtained by adding about 12 lb. of bentonite and 1½lb. of soda ash per dry short ton of concentrate. These additives and occasionally small quantities of fine coal are thoroughly mixed with the filter cake ahead of balling. The swelling property of bentonite improves the green and dry strength of the balls so they can be handled without breakage until they are fired. Soda ash is added for pH control to insure maximum performance of the bentonite and coal is added for more heat in the firing process when required.

The balls, normally ¾ in. to 1-in. diam., are brought to a temperature of 2,350° F. to 2,500° F. in the indurating furnace. Heat for this process comes from three sources: Fuel burned in the combustion chamber, oxidation of the magnetite concentrates to hematite, and coal added to the balls. Pellet strength is developed by grain growth and bridging and, if enough slag-forming constituents are present, by slag bonding. Conversion to hematite is usually close to 100% in the fired pellets.

Initial studies of self-fluxing pellets were made by producing balls on a batch basis under carefully controlled laboratory conditions. The 1-in. balls, uniform in size, were fired in an oxidizing atmosphere in a standard laboratory muffle furnace. The firing procedure consisted of drying 20 balls at 240° F. for 24 hr. in a constant-temperature ventilated oven, then transferring them to the muffle furnace at the same temperature. The furnace was then brought up to the desired firing heat over a 4-hr. period, held at that temperature for 1 hr., and allowed to cool to 500° F. or lower before the fired pellets were removed.

If a ball is to withstand the rigours of mechanical handling and thermal shock before and after being introduced into an agglomerating furnace it must meet certain minimum strength requirements. Three tests have been standardized for comparative evaluation of these properties. The drop test consists of individually dropping ten newly-made balls onto a steel plate from a height of 18 in. The average number of drops the balls withstand before breaking is referred to as the *drop number*. Ten more green balls are subjected to a graduated compressive force on a Dietart core testing machine to obtain *green compressive strength*. Another ten balls are dried in a ventilated oven for 24 hr. then tested on the Dietart machine to determine their *dry compressive strength*. To meet commercial requirements the balls must pass all three tests.

Three methods are now accepted standards for evaluating small quantities of fired pellet—the compression test, the tumble test, and the drop test. The tumble test was varied for evaluation of pilot-plant products where larger quantities of pellets were available, to conform to that currently in use at the Erie taconite plant. This is based on the A.S.T.M. standard coke test with modifications to meet the specific requirements for evaluating pellets.

The sample for this test consists of pellet material remaining on a 3-mesh (0·263-in.) screen, with any fused cluster eliminated.

(1) A 25-lb. (11,320-g.) dry sample of *plus* 3 mesh is used.

(2) This sample is tumbled in an A.S.T.M. coke tumbler for 200 rev. at 24 r.p.m.

(3) The tumbled pellets are hand-screened on a 3-mesh screen.

(4) Material passing through 3 mesh is screened on a Rotap for exactly 3 min. with a Tyler 10-mesh screen.

(5) The percentage *plus* 10 mesh is reported as the tumble index.

An average tumble index of 85 is considered good for production pellets. The specific gravity of the pellets was determined by the displacement-in-mercury method. The apparent specific gravity of the pellet, including voids, is recorded.

Parallel tests with limestone and dolomite revealed a slight advantage in using dolomite in self-fluxing pellets. The finer the dolomite was ground, within the limits tested, the higher the quality of the balls produced.

With 350 lb. of dolomite per dry short ton of concentrates, *plus* the regular additives, balls were made and fired at chamber temperatures of 1,800° F. to 2,350° F. in the muffle furnace. Pellets fired at 2,150° F. are reddish blue, with a very few white specks of dolomite residue. They show considerably improved physical properties. At 2,350° F. they are steel blue and no evidence of the dolomite is visible to the naked eye. The pellets possess excellent mechanical properties. They have shrunk considerably more than those fired at lower temperatures or pellets without dolomite fired at the same temperature. Slag bonding has replaced bridging as the major source of pellet strength.

Pellets produced from magnetic taconite concentrates and fired in the manner described are usually almost completely oxidized to hematite. The varying magnetic fraction can be explained as follows:—

(1) In the presence of available MgO, hematite at elevated temperatures easily forms a magnesioferrite spinel in accordance with the following equation: $MgO + Fe_2O_3 \rightarrow MgO \cdot Fe_2O_3$. Magnesioferrite is strongly magnetic and in polished section cannot be distinguished from magnetite, since both are isometric and isotropic.

(2) In pellets made from magnetite concentrates, where only part of the magnetite has oxidized to hematite, a spinel-type mineral will form in the presence of magnesium oxide, the composition of which is $(Fe^{++}, Mg^{++})\ O.Fe_2O_3$. This mineral is also magnetic, isometric, and isotropic.

The amount of ferrous iron, as well as the total magnetics, varies with both the firing temperature and the amount of dolomite addition. It seems probable that this is related to the formation of $(Fe^{++}, Mg^{++})\ O.Fe_2O_3$ together with possibly a small percentage of residual magnetite. This phenomenon was examined further by the production of a batch of pellets from specular hematite concentrates following the same procedure used in producing balls from the magnetite concentrates. Tube tests recovered 63·73 % of the weight of these pellets as magnetic. Since there was little if any magnetite available $MgO.Fe_2O_3$ was formed rather than the more complex spinel. The small percentage of ferrous iron in these pellets would tend to substantiate this conclusion.

Pilot-plant tests were the next logical step in the investigation. Several tons of dolomite were crushed and wet-ground, all pilot-plant tests being run using 350 lb. of dolomite, *plus* the standard 12 lb. of bentonite and 1·5 lb. of soda ash per dry short ton of commercially-produced taconite concentrates. During the first three tests fine anthracite coal was also added at 20 lb. per ton. A balling drum 3 ft. diameter by 8 ft. long and a shaft furnace 30 in. diameter by 18 ft. high were used for pilot-plant agglomerating at a feed rate of about 0·6 l.t.p.h. The tests were directed toward determining the optimum feed rate and temperature conditions at which pellets of satisfactory quality would be produced. Past experience with magnetic taconite concentrates had shown that at a feed rate of 0·6 l.t.p.h. a combustion chamber temperature of 2,300° F. would produce an excellent fired pellet without the addition of coal. Taking into consideration the added heat requirements for calcining the dolomite and the loss per ton in heat of oxidation of the magnetite that was being replaced by dolomite, it was calculated that about 20 lb. of anthracite fines should be added to each ton of concentrate.

The first test was abandoned when it became obvious from furnace operation and the clusters of fused pellets being discharged that the heat input was too high. The combustion chamber temperature was dropped to 2,100° F., and test No. 2 was conducted without difficulty. For tests 3 and 4 the combustion chamber temperature was 2,000° F. Coal was added for test 3 but not for test 4.

Self-fluxing pellets appear somewhat slower to reduce, which can no doubt be attributed to the sealing off of some areas by the slag bond and possibly to slower reduction of the magnesioferrite. It seems doubtful, however, that reducibility tests give the full picture of the relative value of these products in the blast-furnace. The pre-calcining of the fluxtone and its intimate distribution throughout the charge would appear to be more important factors.

The authors conclude that the tests have provided enough background information to permit operators of commercial plants to proceed with confidence to production of self-fluxing pellets. Some precautions will have to be observed to avoid high pelletizing temperatures, since the large volumes of slagging materials present could quickly form chunks or wall build-up in the unsuspecting operators' furnace. The type of internal bond is different from that obtained in the present product but should provide satisfactory resistance to mechanical destruction. It is probable that an acceptable pellet strength will be obtained at lower furnace-operating temperature than that currently being used in commercial plants.

Within recent months producers have sent out several shipments of self-fluxing or flux-added pellets. Blast-furnace results have not yet become available. It seems reasonable to predict, however, that self-fluxing pellets will show the same degree of improvement over regular pellets that self-fluxing sinter has shown over regular sinter.

Cassiar Asbestos

Economic Geology for March–April contains an article by H. Gabrielse on "The Genesis of Chrysotile Asbestos in the Cassiar Asbestos Deposit, Northern British Columbia." This deposit is situated on the north-west flank of Mt. McDame in the Cassiar Mountains approximately 100 miles by road from Watson Lake, Yukon Territory. The property is owned and operated by the Cassiar Asbestos Corporation, a subsidiary of Conwest Exploration. The Cassiar serpentinite body is one of many ultramafic bodies in the McDame map-area, but the only one in which asbestos of commercial importance has been found. A detailed study of ultramafic bodies in the area indicates that the Cassiar serpentinite body has undergone an unusual combination of serpentinization, fracturing, and metamorphism.

The McDame ultramafic rocks occur in a major south-easterly plunging synclinorium. Two contrasting types of lithology being represented. Typical miogeosynclinal rocks comprise quartzite, limestone, dolomite, slate and argillite of Precambrian to Middle Devonian ages. Typical eugeosynclinal rocks comprise chert, argillite, argillaceous quartzite, greenstone, and graywacke of Upper Devonian and Lower Mississippian ages and overlie Middle Devonian strata with apparent conformity. Ultramafic bodies have intruded the eugeosynclinal assemblage and are in turn cut by granitic rocks of the Cassiar intrusions. West of the asbestos deposit a stock of coarse-grained porphyritic granite, separated from the Cassiar batholith by a 500-ft. screen of contact-metamorphic rocks, has intruded Precambrian and Cambrian strata. Rocks on the Cassiar Asbestos property lie just within the outer limits of the contact-metamorphic aureole related to the granitic rocks. Greenstones near the mine commonly have a crystalloblastic texture and consist largely of tremolite-actinolite, zoisite, clinozoisite, sodic plagioclase and minor hornblende. These greenstones contrast with those farther east that typically have a diabasic or subophitic texture and are characterized by sodic plagioclase, augite, and alteration products of augite. Before alteration most of the volcanic rocks in the area were pyroxene andesites or basalts.

Chrysotile-asbestos veins at Cassiar occur in a mainly concordant, steeply dipping, lenticular serpentinite body that has intruded argillite, chert, quartzite and greenstone. The ultramafic body has a maximum width of about 500 ft. and a minimum length of 1,700 ft. The host rock consists of blocky, locally slickensided, light to dark green serpentinite containing scattered glistening crystals of serpentine pseudomorphous after rhombic pyroxene. Magnetite is fairly abundant and occurs in microscopic veinlets or in veins as much as $\frac{1}{4}$ in. wide. The original rock was presumably a harzburgite. Contacts between the ultramafic body and enclosing rocks are locally well exposed. Argillaceous rocks of the foot-wall are highly sheared, folded, and brecciated. Greenstones along the hanging-wall have been altered to cream-coloured zoisite-quartz-tremolite hornfels. Adjacent to the hornfels and gradational into it over an unknown width is a zone of serpentinite that has been partly altered to fine-grained, dark green, chlorite-antigorite rock. This alteration zone forms an envelope around much of the central ore-bearing part of the body and contains little asbestos fibre. In places along the highly sheared foot-wall, however, high-grade asbestos occurs adjacent to the country rocks.

The chrysotile-asbestos veins at Cassiar are similar to those in many of the asbestos deposits in the Eastern Townships of Quebec. The Cassiar serpentinite body has been highly fractured and most, if not all, fractures in the ore-zone contain asbestos. Locally the veins have a systematic arrangement, some being parallel to joints enclosing strata and elsewhere in the synclinorium. These appear to be cross-joints and related shear joints resulting from a north-east south-west compression and attendant elongation parallel to the axis of the synclinorium. Flat-lying and gently dipping fractures, many of which contain long-fibre asbestos, are apparently tensional joints related to relative movements during folding of strata enclosing the serpentinite body. In addition to the major joints many joints appear to have resulted from relative movements of blocks bounded by joints. The result of the deformation was a complex set of fractures that formed loci for the deposition of chrysotile asbestos.

Most of the asbestos occurs in cross-fibre veins in which the chrysotile crystals are oriented at large angles to the walls. Individual veins may persist for as much as 10 or 15 ft. but generally they are much shorter, particularly where the fractures are densely spaced. They split, branch, and terminate either by merging with veins running in other direction or by pinching out. Short veins without apparent connexion to other veins are commonly lenticular.

The fibre is exceptional both for length and quality. Fibres ranging from $\frac{1}{2}$ in. to 1 in. in length are common. The milled product has relatively low iron content although magnetite is fairly abundant in partings and along the walls of veins. Before emplacement of the granitic rocks the ultramafic body at Cassiar probably consisted essentially of mesh-structure chrysotile, serpophite, and minor bastite. This mineral assemblage is typical of all small ultramafic bodies in the area remote from the contact-metamorphic effects of the granitic rocks. Restriction of asbestos veins to the serpentinite and the general similarity in composition of the veins and host rock suggsts that the vein material was derived from the host serpentinite and that the material had limited mobility. The following succession of events is postulated :

(1) Folding and metamorphism of the serpentinite and enclosing rocks accompanied the emplacement of the Cassiar batholith. As a result the serpentinite body was complexly fractured and brought into a metamorphic environment perhaps equivalent to the upper part of the green-schist facies.

(2) Recrystallization of the serpentinite and the diffusion of asbestos-forming material from the host rock into areas of low rock pressure promoted the growth of chrysotile asbestos. The slightly increased concentration of aluminium in the host serpentinite may have been an important factor in the formation of patchy antigorite. Recrystallization of serpophite probably resulted in a slight decrease in volume, thus effectively increasing the volume of the low-pressure zones.

(3) The growth of fibre in the single-fibre veins kept pace with the rate at which the walls moved apart. In the two-fibre veins the walls moved apart more rapidly than material could diffuse into the openings. Hence fibre grew from both walls in the direction of least pressure and finally met to form a central parting, the irregularity of which reflects the different rates of addition of material from place to place along the veins. Some of the pre-asbestos magnetite and serpentinite chips from the walls of the fractures were pushed outward on top of the growing fibre and thus accumulated along the partings. In many places the remainder of the magnetite formed the base on which the fibre grew. This hypothesis would explain why the magnetite is loosely bound to the asbestos.

(4) Simultaneous with asbestos-formation and under similar conditions the quartz-tremolite zoisite-carbonate veins were formed in the country rock. The composition of fibrous materials in these veins simply reflects the composition of the rocks in which they occur.

(5) Metamorphism along the margins of the asbestos deposit produced the partial envelope of chlorite-antigorite rock. In places along the foot-wall

later shearing brought high-grade fibre adjacent to country rock.

None of the other ultramafic bodies in the area are as highly fractured as the serpentinite body at Cassiar. A study of joints in the McDame area reveals that the major factor influencing the density of fractures in volcanic and ultramafic rocks is the thickness of an individual body. The thick sills of volcanic rocks and large stocks of ultramafic rocks are much less jointed than the smaller bodies. The Cassiar serpentinite is one of the smallest ultramafic bodies in the area and this factor coupled with the structural position of the body on the limb of the synclinorium presumably determined the high density of fractures that were produced by deformation.

Most of the serpentinites in the area have undergone no significant metamorphism since they were formed. Northwest of Blue River, however, metamorphism has been more intense than that at Cassiar and olivine has been regenerated from serpentinite. Much of the ultramafic rock in this area appears to have been little serpentinized prior to metamorphism by the Cassiar granitic rocks. Perhaps the optimum conditions of metamorphism for asbestos growth are reached when feathery reticulated antigorite begins to replace mesh-structure chrysotile, serophite, and bastite.

Colorimetric Determination of Gold

In the *Journal* of the South African Institute of Mining and Metallurgy for March a paper by E. Frankel describes "The Colorimetric Determination of Minute Quantities of Gold by Means of O-Tolidine." The author says the use of o-tolidine as a reagent for gold was first mentioned by W. B. Pollard, who described the colour reaction between Au^{3+} and o-tolidine as a very delicate test. In the past, however, the reaction has not been found suitable for quantitative purposes which is partly explained by W. B. Pollard's own statement which refers to the reaction as follows: "In dilute solutions combinations between the chlorauric acid and the o-tolidine takes place slowly and never appears to reach completion. On addition of ammonium fluoride, used to inhibit the yellow colour given by iron with o-tolidine, an increased reaction takes place and a stronger colour is produced." The author shows that one of the factors influencing the intensity of the colour is the H-ion concentration of a chlorauric solution to be tested and that the stronger colour observed by Pollard on the addition of ammonium fluoride was due to the buffering effect of ammonium fluoride on comparatively acid solutions.

The method described in the present paper should, it is thought, be of assistance when it is desirable to carry out gold assays of cyanide residues or solutions of a low gold content with greater accuracy than is at present possible or practical. The method is not as rapid as the existing gravimetric method but results obtainable with it are more accurate than those obtainable with a sensitive balance when small gold prills, weighing between 0·003 mg. and 0·03 or 0·04 mg., have to be determined.

When o-tolidine is added to chlorauric acid solutions the intensity of the colour produced depends to an appreciable extent on the acidity of the solution. In strongly acid solutions the resulting colour is yellow and not necessarily of maximum intensity; if the pH of the solution is as low as 2 hardly any colour will be observed. As the pH increases the colour changes from yellow to green and becomes blue in very weakly acid solutions. It was found that the maximum intensity of colour is obtained at a pH ranging from 4·6 to 2·6. This pH range was maintained by adding a buffer solution, consisting of equal volumes of 2N hydrochloric acid and 2M ammonium acetate solution. When o-tolidine is added to a thus buffered solution of chlorauric acid a pale green colour results which on addition of more acid turns yellow. The intensity of the yellow colour is under these conditions proportional to the concentration of chlorauric acid present and can be compared with artificial standards, consisting of potassium dichromate and copper sulphate solutions. These standards are similar to those recommended for the colorimetric determination of chlorine by means of o-tolidine. When preparing chlorauric acid solutions consideration must be given to the fact that diluted chlorauric acid solutions, without much excess of aqua regia or chlorine water, are easily reduced by the action of sunlight or minute quantities of reducing substances including even traces of dust in air. If, for instance, air is passed through a solution of gold in chlorine water for the purpose of expelling excess chlorine—which also reacts with o-tolidine—part of the Au^{3+} ion is reduced and cannot be determined with o-tolidine. Nor is aqua regia (unless diluted) suitable for the dissolution of gold if o-tolidine is to be applied afterwards, as any colorimetric determination of chlorauric acid would be illusory in the presence of chlorine or nitrous acid, both producing a yellow colour with o-tolidine. Fortunately, says the author, dilute aqua regia made up of 1 vol. 20% nitric acid and 3 vol. 10% hydrochloric acid does not react with o-tolidine. This acid, when moderately heated, dissolves small particles of gold rapidly, no premature reduction of Au^{3+} ion being noticeable.

Chlorine, nitrous acid, ferric iron, ruthenium, osmic acid, vanadates, and tungstates interfere with the colour reaction, as was previously stated by W. B. Pollard. Silver does not interfere with the reaction as long as the quantity present is insufficient to produce a turbidity or a precipitate in the test solution.

Two or three drops of diluted aqua regia are added to minute quantities of gold in a small porcelain crucible of the size commonly used for parting purposes. The crucible with its contents is moderately heated on a hotplate until all gold is dissolved. If most of the aqua regia should evaporate accidentally it is advisable to bring the contents of the crucible to complete dryness and to heat again gently with two or three drops of diluted aqua regia. The solution is diluted with distilled water and transferred to a calibrated test tube. By means of a pipette 2 ml. of buffer solution are added and the contents well mixed. After adding two drops of o-tolidine reagent the solution is again stirred and, after introducing 2 ml. of 2N hydrochloric acid,

TABLE 1.

Au applied in mg.	*Au determined colorimetrically, mg.*	*Standard used, mg.*	*Depth* in mm.*
0·0240	0·0244	0·0200	10
0·0240	0·0240	0·0200	10
0·0240	0·0232	0·0200	10
0·0120	0·0109	0·0138	10 and 15
0·0120	0·0122	0·0138	10 and 15
0·0120	0·0115	0·0138	10 and 15
0·0060	0·0058	0·0066	15 and 20
0·0030	0·0028	0·0020	15

* Column depth of standard solutions at which comparison took place. With intense colours, as is the case with 0·02 mg. of gold in 10 ml., a standard column depth of 10 mm. gives more accurate results than a longer column.

diluted with distilled water to a known volume, usually 10 ml. The well-mixed solution is then immediately poured into a colorimeter cup and compared with a standard solution, deviating not more than 50% from the sample to be tested. Readings with the colorimeter should be taken within five minutes from the time o-tolidine has been added, as the colour fades slowly on standing. So called " all glass cups " for the colorimeter can easily be kept clean and are to be preferred to glass cups with metal sleeves. By adding two or three drops of diluted aqua regia and 2 ml. of buffer solution the pH of the solution is within the desired optimum. With more concentrated gold solutions aliquot parts of the original solution should be applied. It is then necessary to add a further one or two drops of aqua regia to the aliquot part before adding the buffer solution.

O-tolidine solution.—0·05 gram. of o-tolidine is dissolved in 2 ml. of acetone. After adding 3 ml. N hydrochloric acid the solution is diluted to 250 ml. with distilled water. This solution keeps for several months but eventually turns brown in colour.

Buffer solution.—Equal volumes of 2N hydrochloric acid and 2N ammonium acetate solution.

Aqua regia.—1 volume water-white 20% nitric acid *plus* 3 volumes 10% hydrochloric acid.

Standard solutions.

(*a*) Copper sulphate solution.—1·5 gram. of crystalline copper sulphate and 1 ml. of concentrated sulphuric acid, dissolved in distilled water and diluted to 100 ml.

(*b*) Potassium dichromate solution.—0·25 gram. of potassium dichromate and 1 ml. of concentrated sulphuric acid, dissolved in distilled water and diluted to 100 ml.

For the following examples aliquot parts of a gold solution of known gold content were evaporated in small dishes consisting of lead foil, shaped for the purpose. After adding silver the dishes with their contents were scorified and cupelled in the usual manner. The minute gold prills left after parting were washed with distilled water, dried on a hot-plate, and dissolved in diluted aqua regia as described previously. The results are given in Table 1.

The experimental work relating to the paper, the author says, was carried out during World War II, partly at Government Gold Mining Areas and partly at the writer's private laboratory. The author did not know of W. S. Clabaugh's publication which describes the successful use of o-tolidine for the quantitative determination of gold for the purpose of measuring the thickness of goldplating on jewelry. W. S. Clabaugh measures the intensity of the yellow colour produced by chlorauric acid with o-tolidine by determining the transmittancy of light through the resulting yellow test solutions in a spectrophotometer at a wavelength of 437 millimicrons. No reference is made in Clabaugh's paper to the dependability of the intensity and shade of the colour on the pH of the test solution which consists essentially of a solution of o-tolidine in an excess of N sulphuric acid, apart from traces of chlorauric acid.

The method described by Clabaugh requires the solutions to be tested to be evaporated to complete dryness at a temperature below water-bath temperature in order to avoid decomposition of chlorauric acid ; although an air stream is applied to expedite evaporation at sufficiently low temperatures, it is necessary to control the evaporation temperature by lifting the test beaker with the residue off the water-bath by hand from time to time in order to avoid premature reduction of chlorauric acid.

Clabaugh's method does not seem to have found any application on the Rand and it is possible that the lengthy and delicate procedure, indicated above, is the reason for this.

The procedure described in the present paper can be carried out conveniently and simultaneously on a number of samples with utensils and equipment which are already in use in every Assay Office. It is felt that, in view of the prevailing interest in South Africa to improve the accuracy of modern gold assaying practice, the method presented may be found useful in attaining some of the desired improvement.

Trade Paragraphs

Edgar Allen and Co., Ltd., of Sheffield, in a recent issue of *Edgar Allen News* include some notes on Bamag resonance screens for manufacture of which they have been granted the sole licence.

Clarke, Chapman and Co., Ltd., of Gateshead, in a recent illustrated leaflet give particulars of their Ward-Leonard winch for a.c. or d.c. operation and available in a number of sizes and full load capacities up to 7 tons.

W. C. Holmes and Co., Ltd., of Turnbridge, Huddersfield, in Publication No. 82 describe their Retroflux bag filters, which work at constant pressure and air volume. Filtering areas up to 2,066 sq. ft. are possible in the range of casings available.

C. H. Johnson (Machinery), Ltd., of Adswood, Stockport, have introduced a ¾-yd. 1-ton diesel dumper, Model 1/20, powered by the AVA.1T Petter air-cooled engine. It has a unique articulated chassis combined with positive rear-wheel drive, Ackerman front-wheel steering, and extra high ground clearance.

North British Rubber Co., Ltd., of Edinburgh and Dumfries, announce the appointment of Mr. Edward J. Higgins to the board in succession to Mr. Ludwig C. Boos, who died suddenly in December last. Mr. Higgins, who is now general manager of the International Division of United States Rubber Company, has a long association with the industry in America.

Baker, Perkins and Co., Ltd., Mineral Processing Division, of Blackthorne Road, Letchworth, Herts., have produced No. 1 of the TBE Bulletin in association with Israel Mining Industries Laboratories, Haifa. T.B.E., which stands for tetrabromethane or acetylene tetrabromide, is described and its use in mineral processing outlined and comparison made with dense-media separation methods.

Stephens-Adamson Manufacturing Co., of Aurora, Illinois, announce the formation at Fribourg, Switzerland of Stephens-Adamson International S.A., the purpose being to promote and further expand foreign activities of the company and co-ordinate export sales of the company's three American and one Canadian plants. The new company will provide technical service to foreign manufacturing licensees and engineering representation throughout the world, and also administer and service the company's foreign patents and trademarks.

Industrial Hydraulics, Ltd., of 101, London Road, Reading, state that three new series of hydraulic accumulators have been added to the existing range manufactured. All are of screwed end construction and incorporate safety interlocks to prevent the unit being dismantled while under internal pressure. Series II is for pressures up to 2,000 p.s.i. with capacities ranging from 8 to 20 gallons. Series III is for pressures up to 5,000 p.s.i. with capacities ranging from 1 to 8 gallons. Series IV is for pressures up to 5,000 p.s.i. with capacities ranging from 8 to 20 gallons. Various port sizes and flanges are available.

Allen West and Co., Ltd., of Brighton, on the occasion of their Golden Jubilee have published a bound volume of some 60 pages entitled "The Allen West Story." This sets out in picture and text the history of 50 years of electric control gear development. The foundation of a modest engineering enterprise is recalled, the company then being a tenant of part of an existing factory (The Reason Manufacturing Co., Ltd.) which was subsequently taken over. It now has subsidiaries in Canada, South Africa, and Rhodesia, an associate company in France, and branch offices and agents throughout this country and overseas.

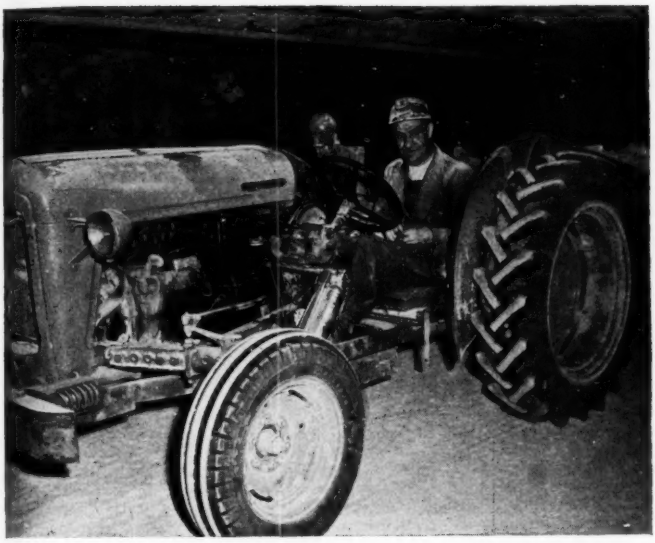
Henry Sykes, Ltd., of 53b, Southwark Street, London, S.E. 1, announce the latest addition to their range of "Univac" centrifugal pumps which is the UVS12, a 12 in. unit capable of delivering 3,500 g.p.m., against a total head from all causes of 32 ft. Particular features are the unchokeable and rapid priming effects, which have been achieved by providing a separate vacuum pump to evacuate any air which may become entrained in the pump body, thus enabling the impeller and volute to be designed purely for pumping duties. The major components are thus a vacuum pump, mounted for direct drive off the engine shaft, the Univac self-priming equipment mounted on the suction side of the pump, a high efficiency unchokeable centrifugal pump and a reflux box on the delivery side of the pump.

Le Tourneau-Westinghouse Co., of 2301, NE Adams Street, Peoria, Illinois, state that the Preco "all-transistor" Dial-A-Slope automatic blade-control unit is now available for installation on their line of motor graders and can be installed on any new or used current model. By the use of this accessory in every phase of operation from roughing in to finishing the productivity of the motor grader can be increased up to 50%. With the Dial-A-Slope control in operation the operator needs to watch only one end of the blade and operate the lift lever which controls it; the other end automatically takes care of itself, maintaining the blade slope the operator has reselected. The result is that the operator can concentrate his entire attention to steering and regulating his depth of cut.

Consolidated Pneumatic Tool Co., Ltd., of 232, Dawes Road, London, S.W. 6, have issued a new 34-page catalogue describing their range of mining equipment. The publication covers all aspects of equipment which the company produces for mining service, the first 12 pages being given to accounts of the class P range, the class R or rotary range, and to the class T, slow-speed horizontal and class FE horizontal balanced opposed ranges of air-compressors. This is followed by 13 pages of detail regarding the extensive range of rock-drilling and roof-bolting equipment produced, followed by sections relating to percussive bits and rods, dust-collecting equipment, sludge pumps, picks, breakers, and digging tools, rail saws, jacks, rams and hoists, and maintenance tools such as impact wrenches, among others. All the sections are illustrated both pictorially and by sectional views and diagrams. The specifications of each class of product are given in concise tabular form.

British Standards Institution, of 2, Park Street, London, W. 1, issue brief details of a British Standard for light and medium rolling stock for mineral haulage in mines (B.S. 3237 : 1960). This new publication provides for the design and construction of good-quality light and medium rolling stock of up to 60 cu. ft. capacity. The vehicles are of the "pit tub" type and are, primarily intended for mineral haulage in mines in general in addition to collieries. (It is intended to produce later a similar standard for the heavier mine car.) Although B.S. 3237 deals with the complete vehicle, care has been taken to avoid restriction on design. Materials and basic requirements for design and construction are specified for bodies and underframes, but for such components as wheels, axles, and pedestals and the drawgear hook the specification goes into greater detail. The range of sizes of fixed and loose wheels has been greatly reduced as compared with present practice. The standard provides guidance on the design of drawgear components such as shackles, rings, and links and design formulae are included.

Massey-Ferguson (United Kingdom), Ltd., of Banner Lane, Coventry, issue some notes on six tractors which are working 200 ft. underground in a Nottinghamshire gypsum mine. Producing 200,000 tons of gypsum annually, the mine is at East Leake, near Loughborough. Because the roof of the mine is only 6 ft. high and in some places as low as 4 ft. 6 in. the tractors have been modified to lower the seating position. The steering column has been moved over to the left and the driver is now sitting just in front of and level with the rear axle on the left side, as may be seen in the illustration. All the tractors have been fitted with a catalytic exhaust system which reduces the amount of carbon monoxide in the fumes and other irritating material, thus conforming with mining regulations. With



Massey-Ferguson Tractor at Work Underground.

special trailers behind the tractors reverse up to a loader at the rock face. With a load of 4 tons on the trailer they travel through the mine to a discharge hopper. By means of an automatic unloading device the bottom of the trailer drops open in three sections and the rock falls on to a conveyor-belt.

RCA Great Britain, Ltd., of Lincoln Way, Sunbury-on-Thames, introduce their electronic metal detector, designed for inspecting conveyed materials such as coal, limestone, and several types of ore. An illustrated leaflet from their associates Radio Corporation of America shows how it will detect the smallest pieces of foreign metal. The apparatus consists of an inspection aperture, through which the conveyor must pass, and a control unit. When metal enters through the aperture a signal is generated which may be used to ring an alarm or actuate any desired control, such as switching off the feeder or spray-marking the metal area. The inspection aperture is available in a number of sizes and in one of two categories—the continuous type through which the belt is threaded or the split type which eliminates the need for splicing the conveyor-belt. Installation and operation are simple. The unit is dust proof, and there are no exposed electrical connexions or moving parts. Power consumption is about 70 W. Detection takes place at conveyor speeds of 25 to 1,000 f.p.m.

Bucyrus-Erie Co., of South Milwaukee, Wisconsin, (British representatives: Ruston-Bucyrus, Ltd., of Lincoln have been awarded a contract to build a mammoth stripping shovel, described as the largest mobile land machine ever made. Its use is expected to lower the cost of mining deeply buried coal which otherwise could not be recovered by the strip mining method.

The shovel will have a dipper capacity of 115 cu. yd. its total working weight will be about 14 million pounds and it will require over 12,000 horsepower to operate with 52 electric motors, ranging from ¼ to 3,000 h.p. each. The entire machine will be supported by hydraulic cylinders, one at each of the four crawler tracks, each independently and automatically operated to keep the machine in a level position at all times. The complete hydraulic system will require 4,000 gallons of fluid. The shovel will be controlled by a single operator located in an air-conditioned cab to which a passenger elevator will provide access. Some other figures given indicate that in 50 seconds the machine will pick up 173 tons of material, dump it 464 ft. away, and swing back for the next bite. The shovel boom will tower 210 ft. in the air.

Henry Wiggin and Co., Ltd., of Thames House, Millbank, London, S.W. 1, have produced a publication, "An Introduction to Wiggin Nickel-Alloys" which not only illustrates the technical applications of high-nickel alloys but introduces the reader to the company. High-nickel alloys can be divided into four categories, corrosion-resistant, heat-resistant, electrical-resistant, and materials with special properties. The first part of the publication is devoted to these properties of the alloys; it explains how they are assessed and into which groups the company's products fall. The latter part illustrates some applications of high-nickel alloys. Another publication recently issued, the latest edition of "Wiggin Nickel Alloys", features an article on bursting discs, explaining their vital importance in industry and how nickel and Monel, due to their corrosion-resistance and creep properties, have proved to be among the most successful materials for this purpose. Gas turbine engine designers to-day are demanding more and more precise criteria in the alloys they employ; "long life for the 'hot end' parts" describes how satisfactory the Nimonic and Nimocast heat-resisting alloys have proved to be in the Rolls-Royce Dart engine.

Armour Hess Chemicals, Ltd., of 4, Chiswell Street, Finsbury Square, London, E.C. 1, referring in a recent note to cationic chemicals as flocculants, state that aqueous suspensions containing particles with negatively charged surfaces lend themselves to flocculation by cationic chemicals provided that these are water-soluble and sufficiently low-priced to warrant their use. Such products are the Arquads (quaternary ammonium salts) and the Duomacs (diamine acetates), produced and marketed by the company. A typical commercial application for the Duomacs and Arquads is the flocculation and settling of colloidal silica where other conventional flocculants have failed. Mineral silica, clays, and iron-ore suspensions are other materials where cationic flocculants give good results. These chemicals are very efficient, and amounts used vary from 0·001 lb. to 0·5 lb. (0·5–250 p.p.m.) of chemical per ton of suspended solids. A particular advantage of the Arquads, which are strong algaecides, is that, simultaneously with their use as flocculants, algae growth is effectively controlled. Where algae growth is a problem the use of this type of flocculant is therefore exceedingly economic. Further data on these flocculants and their mode of use is described in Market Development Memo. No. 10, now available from the company.

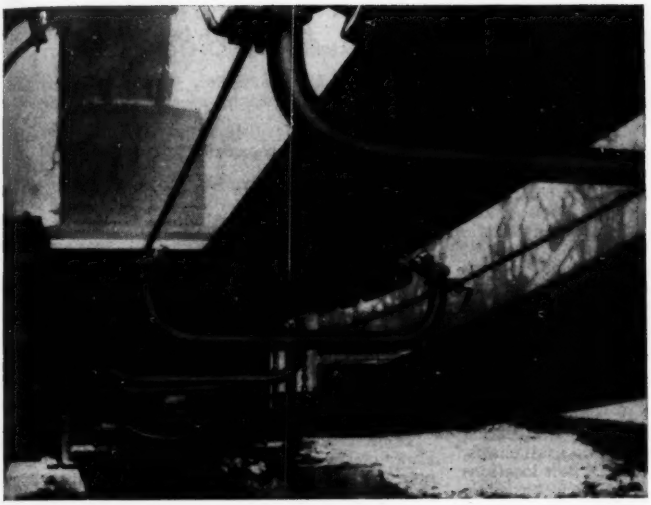
Steel and Co., Ltd., of Sunderland, issue an announcement regarding the three companies—Steels Engineering Products, Ltd., of Sunderland, R. H. Neal and Co., Ltd., of Grantham and Ealing, and F. Taylor and Sons (Manchester), Ltd., of Salford and Glazebury, who manufacture respectively Coles mobile and rail cranes, Neal mobile cranes and other handling plant, and Taylor-Jumbo mobile cranes and mining plant. This states that Neals recently signed an agreement with Unit Crane and Shovel Corporation of America to manufacture Unit cranes, excavators, draglines, and backhoes which will be marketed under the name of Neal-Unit. Hitherto, the three companies have had separate overseas marketing organizations, but, commencing April, 1960, they will combine forces for selling abroad. For this purpose Steels have divided the world into three major zones and a separate marketing company has been created for each. The British Crane Co., Ltd., with headquarters in London, will organize marketing throughout the sterling area, four of the Outer Seven countries, Africa, and Asia. It will operate in three divisions, each covering a separate geographical zone. The International Crane and Excavator Corporation, of New York, promotes sales throughout the whole of the Western hemisphere and certain other dollar areas and a European sales company with headquarters in Switzerland will organize marketing in all European Common Market countries and Austria and Switzerland.

Visco Engineering Co., Ltd., of Stafford Road, Croydon, in a new illustrated leaflet describe the latest addition to their range of dust collectors. This is known as the Visco-Handte and is being manufactured in this country by arrangement with Jacob Handte and Co. of Wurttemberg. It is designed to meet the demand for a wet type dust collector in the solution of recovery problems for which a dry cyclone or a bag type filter is either not suitable or not warranted and is a self-contained unit manufactured in various standard sizes for a range of duties. A number of units can be grouped together according to the volumes of dust laden air to be handled.

Each standard unit consists of a substantial sheet-steel cylindrical casing with an easily removable sludge disposal bin, built-in cyclone, and water eliminator, the whole surmounted by the motor-driven exhaust fan. It is complete with simple floor-mounting supports, water connexions for filling the unit, and hose for cleaning the collector periodically. The collector combines centrifugal and wet collection in the same unit, the dust-laden air being drawn in tangentially and the heavier dust particles deposited in the water by centrifugal action, which also creates a turbulence in the water, breaking it up into a " rain " with which the dust-laden air cannot fail to come into contact. The finer dust particles, which have not been separated out by centrifugal force, are thoroughly wetted in the vortex of the cyclone. A centrifugal water eliminator which is incorporated causes the dust-laden drops of water to be deposited in the sludge bin and cleaned and water-free air to be discharged to atmosphere. In many installations overseas the cleaned air is returned to the work-room without any objectionable results.

Johnson, Matthey and Co., Ltd., of 73–83, Hatton Garden, London, E.C. 1, in a recent announcement state that the development of platinum plating has been limited due to the difficulties associated with conventional plating baths. They have now made available a stable platinum plating solution from which bright, heavy, and coherent deposits may be obtained. This bath, known as DNS Platinum Plating Solution, is based on the complex sulphato-dinitrito-platinous acid, $H_2Pt(NO_2)_2So_4$. The bath is acidic and may therefore be used successfully on electrical components and on printed circuits. Platinum from DNS solution can be deposited directly on to copper, brass, silver, nickel, aluminium, and titanium. For deposition on tin, zinc, cadmium, or steel an undercoat of silver or nickel is necessary. The DNS Platinum Plating Solution is supplied as a concentrate containing 10 g. platinum per 100 ml. of solution. For general use this should be diluted to 5 g. platinum per litre. Glass, earthenware, or plastic tanks should be used. The character of the deposits remains unchanged in the temperature range 30° to 70° C, but the recommended operating temperature is 50° C. At a current density of 5 amp./sq. ft. and at 50° C the deposition rate is 0·0001 in. in two hours. At this rate very accurate control can be exercised over the amount of metal deposited and for the majority of applications these conditions represent the best compromise of efficiency with economy. A faster rate of deposition can readily be achieved by using a solution containing 15 g. platinum per litre at 20 amp./sq. ft. at 50° C. In these conditions a thickness of 0·0001 in. will be deposited in 30 minutes. No agitation is required in using the bath. Where necessary plating can be confined to specified areas by masking with a chlorinated rubber paint. Insoluble anodes are used in the process and these should be of platinum. The anode surface area is not critical.

Joy-Sullivan, Ltd., of Cappielow, Greenock, have announced a new rope conveyor system which employs as a primary component the Limberoller idler already widely used. The new Limberope system enables the features of Limberoller operation to be extended to a much wider range of applications (see illustration). The installation comprises flexible Limberollers mounted in rigid, tubular steel cradles, which in turn are suspended at each end between parallel wire ropes. These " stringers " are held at



Joy-Sullivan Rope Belt Conveyor.

the required height by chains attached to stands, which carry integral return idlers. A feature of interest to the temporary operator is the speed with which an entire system can be set up, dismantled, and relocated to meet various point-to-point requirements. This is facilitated by quick-release handle-bolts on cradle bracket and support stands and further enhanced by the low tension required on the wire stringers between anchor points. The system can be applied to any belt width from 16 in. to 36 in. wire rope diameter varying from ½ in. to ⅝ in. It is claimed that the conveyor is particularly suited to outdoor applications, where the conveyor follows ground contours and spans gullies, etc., without the need for elaborate support structures. On underground mining installations the conveyor is quickly extendable to keep pace with rapidly advancing faces at a rate of approximately 20 ft. per man/hour. Improved load handling characteristics are stated to remain unimpaired in the system. The flexible idler in its swivel mounting conforms to the load and provides a " cushioned " ride which absorbs shock and surge loadings. Belt life is extended because there can be no " pinching " and there are no projections to rip the belt. The troughing catenary exerts a self-centring action on the material, largely preventing spillage and underbelt material build-up. Two bearings only carry the idler, instead of the usual six, and are of the self-lubricating " sealed-for-life " type, situated well above the dirt zone.

International General Electric Co. of New York, Ltd., of 296, High Holborn, London, W.C.1 suggest in some recent notes that the " motorized-wheel " developed by the company, may very well change the concept of all future cross-country vehicles. It can be used for open-pit mining and in other cases where rough terrain prohibits the use of conventional vehicles. The wheel makes possible a 125 ton gross weight hauler combining high performance and large capacity yet having the manoeuvrability of a vehicle one-third its size. Within the hub a few simple parts, an electric traction motor, and gears, give the wheel its driving power. Current for the motors of a vehicle so powered is supplied from a diesel-engine-driven generator or by a d.c. overhead trolley. Each wheel can develop 380 h.p. at the rim. If the motorized-wheels on one side of the vehicle lose traction in loose mud or snow the amount of current supplied to those wheels is automatically decreased and that fed to the wheels that have good purchase is increased Another advantage is the positive and powerful braking system. Travelling at a speed of 35 m.p.h. the vehicle can bring itself to a stop within a distance three times its own length. On deceleration the motors act as generators powered by the forward momentum of the vehicle. and the power generated by the driven motors is dissipated as heat in resistors. (This dynamic braking system acts on the same principle as that used on many diesel-electric and electric railway locomotives.) Among other advantages enumerated are :

It can use full engine horsepower rating over the entire speed range. It will not stall if it meets a momentary excess load. The maximum available tractive effort is two to three times the rated tractive effort. It can climb grades of 10% or more under full load faster than conventional vehicles of equivalent horsepower. Trolley equipped vehicles are proposed for 15% grades at speeds over 10 m.p.h. with full loads. A prototype recently demonstrated its potential power. The vehicle had a gross loaded weight of 110 tons, itself weighing 55 tons, was designed for hauling iron ore, and handled 15% grades fully loaded, turning in only a few feet more than its own length.

Pegson, Ltd., of Coalville, Leicester., make available some notes on a new range of Sultan centrifugal pumps. These suggest that since the advent of the centrifugal pump there has always been the need for a complete range to give maximum duty coverage, within the permitted design limits, using the minimum number of parts and maintaining high efficiencies. These characteristics have never been achieved collectively because of the

practice of building up pump ranges from one or two initially designed sizes. In developing the Sultan range the company has made these features inherent through knowing in advance the extent of the range and treating the full complement of pumps as 42 integrated units ; the result has been a range approaching the ultimate in centrifugal pump design.

The pump is a vertically-split end-suction single-stage unit produced in sizes from 1½ in. to 12 in. suction branch diameter, the range comprising 42 pumps with capacities from 20 to 3,500 gallons per minute. There are six sets of constant hydraulic shapes around which they are designed. Each set of shapes produces a uniform performance pattern so that a 12-in. pump, for example, is a pure geometric enlargement of any other model in the same hydraulic group. By keeping the suction eye constant for all pumps of the same suction branch diameter it has been possible to reduce the number of parts and increase interchangeability. Thus although there are six 4-in. pumps one size of wear ring is common to all. Furthermore the power range—from ¼ to 75 h.p.—is covered by five bearing housing groups and, within each group, all shafts, seals, bearings, caps, keys, and H.D. bolt locations are common. Each pump has the highest possible efficiency, giving maximum output in relation to power input and, due to the mathematical progression of pumps in the range, the overall efficiency of the range is higher than has been achieved hitherto. It is possible for example, to select any pump from the range and, with a full diameter impeller, it is always operating within 6% of peak efficiency and, with a minimum diameter impeller, within 9%. A stable head/quantity characteristic is also a feature.

Compressed Air and Hydraulics Exhibition

Described as the first International Compressed Air and Hydraulics Exhibition and associated with the Second European Fluid Power Conference, this was held in the Empire Hall, Olympia, London, from April 25 to 29. Among the wide range of equipment shown were compressors of various types, air motors, filters, control valves, couplings, hydraulic plant, pumps, and a variety of miscellaneous items. Several companies known for their mining machinery products were among the 120 or so exhibitors.

RECENT PATENTS PUBLISHED

☛ A copy of the specification of the patents mentioned in this column can be obtained by sending 3s. 6d. to the Patent Office, Southampton Buildings, Chancery Lane, London, W.C. 2, with a note of the number and year of the patent.

26,817 of 1957 (831,240). INTERNATIONAL MINERALS AND CHEMICAL CORPORATION. Electrostatic concentration of minerals; process, and apparatus.

31,659 of 1957 (831,003). MICROCYCLOMAT CO. A synergistic fluid energy reducing and classifying unit.

35,182 of 1957 (829,972). UNIVERSAL OIL PRODUCTS CO. Recovery of platinum metals from composites with alumina.

11,988 of 1958 (829,896). DOMINION COAL CO., LTD. Method and machine for mineral mining.

12,259 of 1958 (830,582). HISCHMANN GEB. Comminution and separation apparatus.

15,152 of 1958 (829,899). HORIZONS INC. The preparation of zinc.

NEW BOOKS, PAMPHLETS, ETC.

☛ Publications referred to under this heading can be obtained through the Technical Bookshop of *The Mining Magazine*, 482, Salisbury House, London, E.C. 2.

Copper Costs and Prices : 1870–1957. By ORRIS C. HERFINDAHL. Cloth, octavo, 260 pages, illustrated. Price 48s. Baltimore : John Hopkins University Press. London : Oxford University Press.

The Redruth and Chacewater Railway, 1824–1915. Paper covers, 56 pages, illustrated. Price 6s. 11d., post free. Truro : D. B. Barton, The Truro Book Shop.

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International Tin Research Council : Annual Report, 1959. Paper covers, 36 pages, illustrated. Greenford, Middx. : Tin Research Institute.

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Bechuanaland Protectorate : Geological Survey Report, 1958. Paper covers, 42 pages, with map. Price 3s. Lobatsi : Geological Survey.

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Western Australia : Geological Survey Bulletin No. 112. Miscellaneous Reports for 1955, with 31 plans in separate atlas. Paper boards, 218 pages. Perth : Government Printer.

Selected Index to Current Literature

This section of the Mining Digest is intended to provide a systematic classification of a wide range of articles appearing in the contemporary technical Press, grouped under heads likely to appeal to the specialist.

* Article in the present issue of the MAGAZINE. † Article digested in the MAGAZINE.

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